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THE RELATION BETWEEN THE TENSILE STRENGTHS OF LONG AND SHORT BARS.

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To find the tensile strength of any material, it is customary to break a number of specimens, and take the average of the breaking weights as the ultimate tensile strength of the material. The strength of the individual specimens varies from the average, and of these variations it may be said that—

1°. Positive and negative variations are equally probable;

2°. Small variations are much more probable than large ones; and

3°. If the material be good, extremely great variations seldom or never happen.

Three similar propositions form the basis of the law of probability of accidental errors; namely,

1°. Positive and negative errors are equally probable;

2°. Small errors are much more probable than large ones; and

3°. Very large errors do not occur.

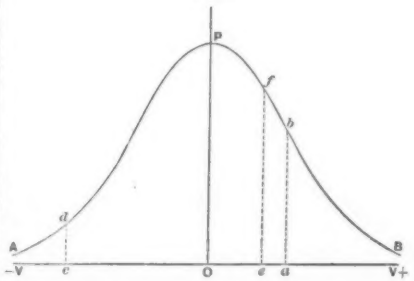
From this it seems reasonable to expect the variations in the strength of a material to follow the same law as accidental errors; or, what amounts to the same thing, it appears that we may consider the variations as accidental.

As an experimental proof that the laws in the two cases are the same, we may compare the number of times in which the variation in the strength of copper wire fell between certain limits, with the number of times it *should* by the law of error fall there.

Variation.	By experiment.	By theory.
Between 0 and .5P	46	46
" .5P " .P	51	43
" P " 1.5P	31	32
" 1.5P " 2P	28	25
Above 2P	24	34
	180	180

Considering that the breaking weights were taken in twentieths of a pound, and the averages calculated to hundredths, the agreement between the two sets of numbers is as great as could be expected.

Fig. 1.



It may be useful to explain to some extent the law of errors. It is represented by a curve which has a shape similar to AB (Fig. 1). The ordinates of

this curve represent probabilities; the abscissae errors. The probability of a positive error Oa is ab; of a negative error Oc, is $\overline{cd}$. The whole area included between the curve and the axis of errors is equal to unity. The probability that an error will fall between $+$Oa and $-$Oc is given by the area $dcab$Pd. The curve is symmetrical with regard to the line PO, as it should be from the first proposition on errors; hence, the area APO$=$BPO$=\frac{1}{2}$. If an ordinate be drawn dividing the surface BPO, or APO, into two equal parts, the error which corresponds to this ordinate is called the *probable error*, and it is defined by the fact that errors numerically greater than the probable error are equally probable with errors numerically less than the probable error. If Oe is the probable error, PO$ef=\frac{1}{4}$. The probability that an error will be either negative or less than the probable error is $\frac{3}{4}$. The probability that an error will be either positive or less than Oc is equal to the area dcBP$d=.5+dc$OP$d=.5+$A$_c$.

Substituting "variation" and "probable variation" for "error" and "probable error," we may apply the law and the curve to the variation in the strength of a material.

The doctrine of probabilities teaches that, if the probability of an event be p, the probability that it will happen n times in succession will be p^n; for example, if a coin be tossed up, the probability that it will fall with the head up is $\frac{1}{2}$; that it will fall n times in succession with the head up is $(\frac{1}{2})^n$. In like manner if a number of pieces of iron one inch long give an average ultimate tensile strength of 60,000 lbs. per square inch; the probability that any other similar piece will have a strength greater than this is $\frac{1}{2}$; that two pieces in succession will have a greater strength, $\frac{1}{4}$; that n pieces in succession will be stronger than the average, is $(\frac{1}{2})^n$.

Suppose that many pieces of cross section c, and length one inch have been tested for tensile strength with an average result S$_o$, and a probable variation in one piece of P$_o$; what will be the probable average strength, S$_n$, of pieces of the same cross section and a length n inches?

Knowing the probable variation in a piece one inch long, we are able to construct the curve showing the probability of any and all variations in a piece of this length. From this curve we can obtain the probability that the piece one inch long will break between any limits of variation. The probability that an inch-piece will break above a negative variation $-x$ is $.5+$A$_x$, in which A$_x$ represents the probability that the piece will break between o and $-x$. In a piece n inches long there are n pieces one inch long; the probability that any one of these will break above $-x$ being $.5+$A$_x$, the probability that all of them will break above this limit, or that the strength of the whole piece will be at least S$_o-x$, will be

$$(.5+\mathrm{A}_x)^n.$$

As S$_x$ is an average, it is as probable that a piece n inches long will break above it as below it; hence the probability that a piece n inches long will break above it is .5. We have then

$$(.5+\mathrm{A}_x)^n=.5,$$

in which A$_x$ is the unknown quantity. We easily obtain

$$\mathrm{A}_x=\sqrt[n]{.5}-.5;\ \text{or}\ 2\mathrm{A}_x=2(\sqrt[n]{.5}-.5).$$

The question is put in the last form to enable us to use tables, which are already prepared, showing the probability that an error, or in our case a variation, will be numerically less than a certain multiple of the probable variation. Such tables may be found in Merriman's Method of Least Squares, page 112; or in Chauvenet's Astronomy, vol. II., table IX A. Entering these tables with the argument 2A$_x$ we find x; and as $x=\dfrac{\text{Variation}}{\text{Probable Variation}}$ we get

Variation$=x\times$ Probable Variation.

It will be seen that if n is greater than one, x must necessarily be negative; hence we conclude that as the length of pieces is increased, the probable average strength is diminished. This has been shown experimentally many times; for example, Trautwine (Engineer's Pocket-book, page 179) mentions an experiment made by Lieut. Shock, in which a specimen of steel whose length was small (turned down at one point) gave a strength of 79$\frac{1}{2}$ tons; when turned down for a length of 14 inches, it bore only 60 tons. Kirkaldy (experiments on wrought

iron and steel) gives experiments on specimens of three kinds of iron, which were turned down at a point, and for over three inches, and in no case did the long specimens have as great tensile strength as the short ones.

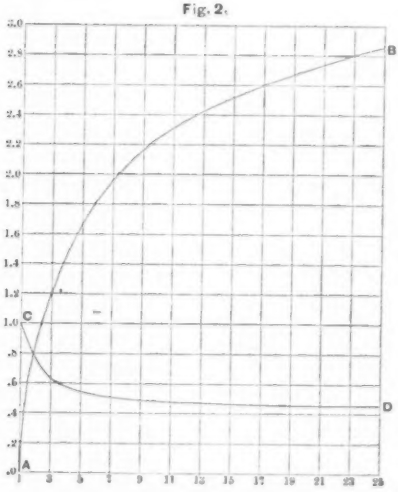
If now we place $n=1, 2, 3,$ &c., and find the corresponding values of x, we shall have the diminution of strength for these lengths in terms of the probable variation of one specimen one unit long. The following table gives the values of x for values of n from 2 to 28:

TABLE SHOWING THE PROBABLE LOSS OF TENSILE STRENGTH FROM INCREASING THE LENGTH OF THE PIECE n TIMES, x BEING IN UNITS OF THE PROBABLE VARIATION OF A SPECIMEN OF A LENGTH UNITY.

n	x	n	x	n	x	n	x
1	0	8	2.05	15	2.51	22	2.78
2	.81	9	2.14	16	2.56	23	2.80
3	1.21	10	2.22	17	2.60	24	2.82
4	1.48	11	2.29	18	2.64	25	2.85
5	1.67	12	2.36	19	2.67	26	2.87
6	1.83	13	2.41	20	2.71	27	2.90
7	1.95	14	2.46	21	2.74	28	2.92

The curve AB in Fig. 2 shows the same thing, the multiples of n being measured horizontally, and the multiples of the probable variation of a single piece unity long being measured vertically.

Fig. 2.



As a proof of this theory, and as an example of the necessary calculations, I will give the following test made on annealed wire of Japanese copper: All the tests made in this set are given except two, in both of which the wire slipped in the clamps; one of these was a 1 inch piece, which when tried again broke at 26.25; the other, a 4 inch piece, broke afterwards at 27.15. As the ultimate strength of the wire is changed by straining it beyond its limit of elasticity, these two tests were discarded. The lengths were measured between the clamps of the testing machine; the specimens were cut off of the coil as they were tested, first a 1 inch specimen, then a 4 inch specimen, then 8 inch, 12 inch, 16 inch specimens and so on again through the series. When a wire slipped, another specimen of the same length was immediately cut off and tested.

TENSILE STRENGTH OF ANNEALED WIRE OF JAPANESE COPPER.

Length.	1 in.	4 in.	8 in.	12 in.	16 in.
Pounds.	27.35	27.00	27.00	27.00	26.90
	27.55	26.90	26.60	26.45	26.10
	26.30	26.20	26.25	26.10	25.90
	26 90	26.45	25.90	25.65	26.15
	26.80	26 40	26.40	26.20	26.20
	27.30	26.90	26.70	26.55	26.65
	27.35	26.90	26.60	26.45	—
Average	27.08	26.68	26.49	26.34	26 32
Prob. variation of one piece..	± .295	± .20	± .21	± .28	± .25
Prob. variation of average....	± .12	± .08	± .09	± .11	± .10
Loss of strength by exp't.....		.40	.59	.74	.76
Loss of strength by $x\times 29.5$....		.436	.604	.70	.754

It will be seen that the loss of strength found by experiment agrees very closely with that found by the formula $x\times 29.5$.

If now we place

$$(.5+A_{x_1})^n=\tfrac{1}{4}$$

and find the value of x_1, this value of x_1 will be that multiple of the probable variation of one piece of length unity.

which corresponds to the probable variation for a piece of a length n.

Solving, we have

$$A_{x_1} = \sqrt[n]{\tfrac{1}{2}} - .5 = \sqrt[2n]{.5} - .5.$$

We can easily get the value of x_1 from our table by using the argument $2n$ instead of n. Then $(x_1 - x) \times$ probable variation of one test piece = probable variation of piece whose length is n. Thus we find for

4 in.	8 in.	12 in.	16. in
±.17	±.16	±.13	±.12

It could not be expected that the probable error found by so few experiments would agree with that given by the theory; yet for all the experiments on long pieces it is less than for the one inch pieces.

The curve CD Fig. 2 shows the probable variation of strength of a bar n units long, in terms of the probable variation of a bar a unit long.

In rolled bar irons, as the smaller sizes have been re-heated more times than the larger ones, and are more thoroughly rolled, it is probable that there is no law giving with any great accuracy their relative strengths. In forged bars, however, it is more probable that the material in bars of different sections is uniform, consequently their relative strengths can be calculated.

If a test-bar of one inch section has a strength of S_0, it is probable that a bar of the same length and of a section m times as great would have a strength mS_0. If the probable variation of the test-bar be P_0, that of the second bar will be $\sqrt{m}P_0$. The relative probable variation, or the probable variation divided by the probable strength, therefore, becomes smaller as the section of the bar is made larger.

Let us now apply these two laws to an example. Suppose a test of many pieces one foot long and one square inch in section, shows that the average tensile strength of such pieces is 60,000 lbs. with a probable variation of 10,000 lbs.; what are the probable strength and probable variation of a bar whose length is 20 ft., and whose section is 9 inches?

The probable strength of a piece one foot long and nine inches in section is 540,000 lbs.; and its probable variation $3 \times 10{,}000 = 30{,}000$. Increasing the length 20 times its probable strength is diminished $30{,}000 \times 271 = 81300$; hence its probable strength for a length of 20 ft. is $540{,}000 - 81300 = 458{,}700$. The probable variation from this is $(3.14 - 2.71)\ 30000 = 12900$ lbs.

It is to be hoped that those who have testing machines and occasion to make numerous tests will publish either all their individual results, or will give the probable variation as well as the average strength of the materials which they study. It really tells but little about a material to give only the average breaking weight; uniformity of strength, or a small probable variation, is a very valuable quality, and without knowing whether a material has a small probable variation or not, no engineer can properly decide what factor of safety shall be used in designing a structure.

THE PRACTICAL STRENGTH OF BEAMS.

By BENJAMIN BAKER, M. Inst, C. E.

From Selected Papers of the Institution of Civil Engineers.

THE theory of transverse stress has engaged the attention of mathematicians for many years, and certain hypotheses have been, and still are, generally accepted, although every practical engineer knows that, in the majority of cases, the calculated results based upon these hypotheses are widely at variance with those obtained by experiment. Engineers, however, cannot afford to wait until a rational theory of transverse stress is agreed upon, and no doubt many engineers beside the author have framed certain rules for their own guidance, which have given results agreeing with experiment, and otherwise answered their purpose as well as if an unassailable theory had been arrived at.

A comparison of these practical rules can hardly fail to be useful, both to the scientific experimentalist who has leisure to make special tests to elucidate a theory, and to the engineer whose first object is to make sure that his structure possesses the required strength. The author, therefore, proposes to illustrate, as briefly as possible, the method of calculation which he has found, during the past fifteen years, to give satisfactory results in the instance of many thousands of tons of beams of every variety of cross section.

Of all classes of iron and steel beams, rails hold the most important position; for not only do they outnumber all other descriptions of beams by hundreds of millions, but at least a thousand pieces of rails are tested to destruction, purposely and in actual work, for every single specimen of rolled joist or riveted girder. Rails, therefore, and at the present time steel rails, are entitled to first consideration, and the general applicability of the methods of calculation set forth will be subsequently tested by a comparison of the calculated and experimental results in the instance of other forms of beams and girders.

The experience gained from the tests of upwards of a hundred thousand tons of steel rails, has satisfied the author that there could be no more fallacious way of comparing the merits of two sections of rail, as regards strength, than by taking a specimen of each at random and testing one against the other as a beam. As ordinarily manufactured the strength of steel varies so widely that by such a process it might be concluded that a 60-lbs. rail was as strong as an 84-lbs. rail, both being well designed sections and of a good quality of steel. A large number of specimens must be tested to obtain average results equally trustworthy with those which can be obtained by any unskilled person, in less than an hour, by the simple mechanical process of investigation set forth in this paper.

Although the stress occurring upon a rail in actual work is a matter outside the limits of theoretical investigation, it has been conclusively demonstrated in practice that a certain transverse strength is desirable; and it is expedient, therefore, for the engineer in all cases to ascertain whether a proposed rail possesses that desirable strength or not.

On paper, the problem presented by a cross-sleeper road appears to be identical with that of a continuous girder bridge of seven or eight spans, and the late Mr. Heppel and many others have so treated it. As a matter of fact this method is entirely wrong, both on theoretical and practical grounds. Theoretically so, because the rail rests upon elastic supports in the form of compressible wooden sleepers, and practically so, because of the uncertainty as regards packing of ballast and state of decay of the timber. The experiments of Baron von Weber, M. Inst. C.E., have shown that an average wooden sleeper compresses about one-fifth of an inch under a pressure equivalent to the weight on a heavy driving wheel; and as an ordinary rail would deflect only that amount if the sleeper were entirely removed, and the rail supported by the adjoining ones, it will be seen at once how utterly misleading must be any conclusions based upon the hypothesis of rigid supports.

Probably the most correct hypothesis will be to look upon a rail in the same light as the distributing girder of a suspension bridge, since, within certain limits, the required strength will not be affected by the distance apart of the points of support or suspension. Take for illustration the common case of a flange rail, laid direct on a bridge floor, formed simply of 8-inch planks spanning the 14 or 15 feet space between the main girders. Here the deflection of the rail between any pair of the most heavily loaded wheels will be small compared to the deflection of the planking, so the rail acts as a true distributing girder with calculable strains. To distribute the weight, say, of a 45-ton six-wheeled tank engine having a 15-feet wheel base, with approximate uniformity over the planking, the rail must obviously be strong enough, as an imperfectly continuous beam of 7 feet 6 inches span, to carry a distributed load of at least 1 ton per lineal foot. Allowing one-half of the maximum reduction obtainable by perfect continuity, the maximum bending moment on the rail will be $\frac{5 \times 7.5^2 \times 12''}{6 \times 8} = 70$ inch-tons—a stress

which an 80-lbs. iron rail could very well sustain, as it would be about one-fourth of the breaking stress.

Having reference to the elasticity of the sleepers, imperfections in packing, and other contingencies, it is probable that the above case not unfairly represents the condition of a rail in an ordinary piece of permanent way; and it follows that, however close the sleepers be spaced, even to touching, the rail must have the stated transverse strength, or it will not distribute the weight over the ballast without itself being strained beyond the limits found advisable in wrought-iron structures subject to repeated bendings.

Again, practical contingencies as regards decayed sleepers, and bad ballasting, clearly indicate that the strength of the rail in a cross-sleeper road should be sufficient to carry the load without exceeding the limit of elasticity, even if one intermediate sleeper were wholly removed from under the rail. Allowing as before for imperfect continuity, it will be obvious that the distance apart of the sleepers must be something less than one-fourth of the wheel base of the before-mentioned 45-ton tank engine, or 3 feet 9 inches, or the stress would be double that occurring on the planked floor, and consequently reach the limit of elasticity. With the sleepers 3 feet apart, the 80-lbs. iron rail would not be permanently bent by the heavy engine, even if an intermediate sleeper failed, as in practice is often the case, to yield any support to the rail.

On the Metropolitan railway the average breaking weight of the original rail, when partly worn, would not be more than 16 tons, if one of the intermediate sleepers failed to support the rail. As the weight on the driving wheel is 8 tons, plus the amount due to oscillations and other contingencies in working, it follows that, under the latter conditions, the strain would pass the limit of elasticity, and that after repeated bendings, the rail would break through the holes in the bottom flange. This was found to happen in so large a number of instances as to indisputably establish the fact that the limit of elasticity was frequently passed, and that the repeated bendings under the five-minute train service broke the rails by tension at a point where, if the supports were only approximately rigid, compressive strains alone would occur.

There are sound theoretical grounds, therefore, for the conclusion, long since arrived at in practice, that an 80-lbs. iron rail, with sleepers 3 feet apart, is the lightest permanent way which it is expedient to adopt for heavy traffic, if it is intended to avoid strains beyond the elastic limit, and the "bad top" so characteristic of not a few lightly railed but heavily-sleepered American lines.

A steel rail on the average may be considered as about 50 per cent. stronger than an iron rail of the same section, and it was not unreasonably assumed at first that the introduction of steel would lead to the use of correspondingly lighter rails; but this has not proved to be the case in practice, probably for the following reasons: The effective strength of a rail is not its strength when new, but when worn, and as a steel rail is expected to become disabled only by fair wearing away of the head for $\frac{3}{4}$ inch, or even more, and not by crushing or lamination, it is necessary to compare the strength of the steel rail so worn with that of the less worn iron rail; and if this be done it will be found that a considerable call is ultimately made upon the increased strength of steel, though the rails when new be of the same weight. The reintroduction of the "bull-headed" rail of 1835 is both scientifically and practically right, because it provides a large area for wear in the head, and recognizes the fact that the top and bottom tables of a rail are each subject to alternating tensile and compressive strains of equal intensity, and require therefore in the worn rail equal areas. A well-proportioned bull-headed steel rail will lose at least 25 per cent. of its weight, and 25 per cent. of its strength before the top table is unduly worn; so, having reference to this fact, and to the great variation in the strength of the steel in rails, it would be clearly inexpedient to make the large reduction in weight, which superficial investigation might at first indicate, as a consequence of the substitution of steel for iron.

A consideration of the probable strains occurring in a rail is of great interest, as affording, beyond all comparison, the most

important data for arriving at trustworthy conclusions in matters relating to the endurance of iron and steel under severe stresses. As already observed, no other class of beam includes a tithe of the number of examples, nor is any other description of beam subjected to the millions of repeated bendings, and instantaneous reversal of strains, that a rail undergoes in ordinary working.

One consequence of the substitution of steel for iron rails has been a greatly increased difference in the maximum and minimum strength of a given piece of permanent way. It is extremely difficult to ensure even a moderate degree of uniformity in the strength of the steel rails, manufactured from a given specification. In one lot of about 20,000 tons, rolled in three different works, the author found in each instance that the tensile strength of rejected rails ranged at times from about 32 to 54 tons per square inch, though the average of the whole, judging from the tests, must have been within 5 per cent. of that aimed at by him, namely, 40 tons. Here there occurs a range of nearly 70 per cent., which is far greater than anything the author has met with in the instance of iron rails. It is worthy of note that the recent exhaustive inquiry, of the Pennsylvanian Railroad Company, into the comparative endurance of rails of different degrees of hardness, has led to the specification of steel having as low a tensile strength as 29 tons per square inch. Steel rails of this description would be little more than 10 per cent. stronger than good iron rails of the same section, and considerable further experience is required before this great sacrifice of strength can be said to be justified. Where the pernicious plan of making holes in the flanges of rails is still in force, as it is on some Irish lines, the steel undoubtedly can hardly be too soft; and in such cases the author aims at a mean tensile stress not exceeding 35 tons per square inch, in lieu of the 40 tons which he otherwise adopts.

Although the tensile strength and ultimate extension afford perfectly satisfactory evidence of the quality of steel in the form of rails, the necessary tests are inconvenient and costly in application. The rough-and-ready falling weight test is simple and effective, but it is not possible to deduce directly therefrom the strength and ductility of the steel. The lever test is next in order of simplicity, and the results thus obtained, when properly interpreted, do disclose those elements, as completely as if the cost and labor had been incurred of planing out strips and testing them under direct tensile stress. Some simple and trustworthy plan, of converting results obtained under transverse stress into the equivalent results under direct tensile stress, is thus a desideratum of no little practical importance; and the author now submits the method which he has found satisfactory in the instance of many thousands of tons of rails of varied sections.

The average results of a very large number of experiments show that as regards deflection under transverse stress, a rail as a beam behaves exactly in accordance with the ordinarily accepted theory, with this important distinction, that the maximum deflection within the elastic limit is greater than theory would indicate, by an amount ranging from 5 to 50 per cent., according to the cross section of the rail. Experiments by Mr. W. H. Barlow, F.R.S., President Inst. C.E., on other descriptions of beams would have indicated such a conclusion, and that the increase in the elastic deflection, as in the elastic and ultimate strength, must necessarily be included within the limits of 0 and 70 per cent., because the increase is nil in the instance of a steel-plate girder with a thin web, and averages 70 per cent. in a solid bar of rectangular cross section. In estimating the probable increase in the case of a beam, such as a rail having a cross section between these two extremes of girder and bar, the first impulse naturally would be to assume that it would approach the limit of 70 per cent. in the same proportion as the section of the rail approached the solid rectangular bar, that is to say, that the increase would be 70 per cent., multiplied by the sectional area of the rail, and divided by the area of the enclosing rectangle. This simple assumption the author has found to be sufficiently near the truth for all practical purposes, as it leads to equally useful results when applied to a 5-inch flange rail—the widest now rolled—and to a bull-headed

rail with a 2-inch bottom flange. Any great refinement in calculations of this sort is wholly unnecessary, for there is good reason to suppose that every cubic inch of steel in a rail differs somewhat in tensile strength from its neighbor, whilst internal tension and other elements further complicate results. All that can be attained, and all that is practically necessary, is a knowledge of the relative strengths of different cross sections of rail, and of the absolute strength of a given rail made of steel of a stated tensile strength, within a sufficiently small percentage of the actual results obtained, not in a few, but in a fairly large number of direct experiments.

Accepting the above hypothesis as to increased strength under transverse stress, it is only necessary to know the moment of resistance of the cross section of the rail as a girder, or the effective depth in inches multiplied by the effective flange area in square inches, to be enabled to convert results obtained under transverse stress into their equivalents in direct stress.

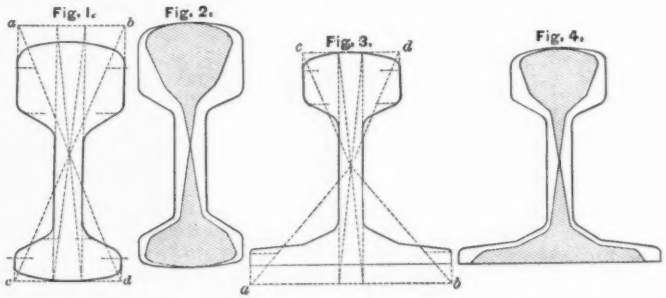
The required moment of resistance, and other information, are readily obtained mechanically as follows:

1st. Cut a template of the rail out of a sheet of tin-plate or thin zinc, and also a strip 1 inch wide, and about 10 inches long. Place the template in one of a pair of letter scales, or cheap laboratory scales, and balance it by cutting a portion off the 1-inch-wide strip. The length so cut off will obviously give the area of the rail in square inches, and this multiplied by ten will be the weight in pounds per yard if of iron; if of steel, add from 2 to 3 per cent.

2nd. Balance the template flatwise on the point of a needle to obtain the center of gravity and neutral axis of the given cross section.

3rd. Transfer the neutral axis so obtained to the drawing of the rail. In the bull-headed section this axis will of course be nearer the top than the bottom of the rail, in the flange section generally the reverse; in either instance set up, or set down, as the case may be, a horizontal line a to b at the same distance from the neutral axis as the part c to d. By a series of perpendicular lines, transfer the width of rail flange, thickness of web, &c., to the lines a to b and c to d, and draw lines radiating to the neutral axis, as shown on Figs. 1 and 3, the intersection of which, with the horizontal lines indicating the thickness of head and flange, &c., will at once give the boundaries of the areas of uniform stress, as shaded on Figs. 2 and 4.

4th. Cut templates of these figures



out of tin-plate or zinc as before, place one in each scale-pan of the balance, and if correctly executed, the weight of the portion above the neutral axis will exactly balance that below. Put both templates into one pan, and balance them by cutting a portion off the 1-inch-wide strip, when the length so cut off divided by 2 will of course give the area of each template, or as it may be termed the effective flange area of the rail.

5th. Balance each template on the point of a needle to obtain the center of gravity. Transfer these centers to the drawing, and the distance between them will give the effective depth of the rail, which multiplied by the area will give the required moment of resistance. The latter may also be quickly obtained with

a sufficient degree of accuracy by cutting the templates out of drawing-paper, and finding the centers of gravity as before by balancing, but calculating the areas instead of weighing the templates.

The moment of resistance so determined, will be the minimum moment applying to the lower portion of a bull-headed rail, and, generally, to the upper portion of a flange rail. The effective moment of resistance for the other half of the rail will obviously be greater, in the inverse ratio of the distances of the extreme fibers from the neutral axis, as exhibited in the application of the above method of calculation to the solution of the following problems respecting a bull-headed rail and a flange rail:

a. A bull-headed rail, 5.6 inches deep, by 2.5 inches wide, weighing 82½ lbs. per yard, sustains an ultimate load of 35 tons applied at the center of 60-inches bearings; required the equivalent direct tensile strength of the steel.

b. A flanged rail, 4.75 inches deep, by 4.75 inches wide, weighing 72½ lbs. per yard, is made of steel having a tensile resistance of 43 tons per square inch, and an elastic limit of 54 per cent; required the weight applied at the center of 60-inches bearings, which the rail will support without permanent set.

Dealing first with the bull-headed rail:

1. On weighing the zinc template of the rail the sectional area is found to be 8.05 square inches.

2. On balancing the template on the point of a needle, the center of gravity, or neutral axis, proves to be 2.57 inches from the head, and 3.03 inches from the bottom flange of the rail.

3. The distance 3.03 inches being set up above the neutral axis, the figures of uniform stress are drawn, and templates in zinc prepared as already described.

4. On weighing the two templates, their joint area is found to be 4.8 square inches, and the "effective flange area" therefore is 2.4 square inches.

5. Balancing the templates on the point of a needle, the center of gravity of the upper template proves to be 1.74 inch above the neutral axis, and of the lower template 2.31 inches below the same point. The "effective depth" consequently is 4.05 inches, and the moment of resistance M = 2.4 square inches × 4.05 inches = 9.7.

The "apparent" tensile strain f on the steel under the given load of 35 tons at the center of 60-inches bearings will therefore be:

$$f = \frac{35 \times 60''}{4 \times 9.7} = 54 \text{ tons per square inch.}$$

The ratio of the rail to the enclosing rectangle is $\frac{8.05 \text{ sq. in.}}{5.6'' \times 2.5''} = 0.57$, which, multiplied by 70 per cent., gives 40 per cent. as the probable difference between the "apparent" tensile strength developed under transverse stress, and the direct tensile strength of the steel of which the rail is made. Dividing the calculated 54 tons "apparent" strain by 1+40 per cent., the equivalent direct tensile strength $= \frac{54}{1.4} = 38.6$ tons per square inch.

Referring to Mr. Price Williams' paper on the "Permanent Way of Railways," from which, for convenience of reference to the already published table of tests, the above example was taken, it will be found that in the four samples tested, the mean ultimate load at 60-inches bearings was 35 tons, and the mean direct tensile strength of the steel strips, cut out of the bottom flange, 39 tons per square inch.

The method advanced gives, therefore, satisfactory results as regards the bull-headed rail, and its applicability to the flange rail section will now be tested.

Proceeding with the 72½-lbs. flange rail in the same manner as with the 82½-lbs. bull-headed rail, the following data are as readily obtained:

1. Sectional area of rail = 7.1 square inches base.

2. Center of gravity = 2.5 inches from head, and 2.25 inches from flange.

3. Effective flange area = 2.25 square inches.

4. Center of gravity of upper and lower areas = 1.75 inch and 1.85 inch respectively, from neutral axis. The "effective depth" therefrom = 3.6 inches, and the moment of resistance M = 8.1 in compression, and $8.1 \times \frac{2.5''}{2.25} = 9$ in tension.

5. Ratio of rail to enclosing rectangle $= \frac{7.1 \text{ sq. in.}}{4.75 \times 4.75} = .31$; which multiplied by 70 per cent., gives 22 per cent. as the

probable increased strength in this instance, instead of 40 per cent. as in the bull-headed section.

The "apparent" tensile strength at the elastic limit, under transverse stress, with the given conditions of 43 tons ultimate direct tensile strength, and an elastic range of 54 per cent. will be 43 tons $\times 54$ per cent. $\times (1+22$ per cent.$) =$ 28.4 tons per square inch; and the corresponding weight applied at the center of 60-inches bearings required to produce an appreciable "set" will be:

$$W = \frac{4 \times 28.4 \text{ tons} \times 9}{60 \text{ inches}} = 17.04 \text{ tons.}$$

The mean result obtained by the author in six experiments, on rails having the direct tensile strength of 43 tons per square inch, was 17.2 tons; and equivalent results were obtained with numerous other specimens having higher and lower tensile strengths.

The simple hypothesis, that the increase in the transverse strength of a flanged or double-headed steel rail, beyond what the ordinary theory would indicate, is equal to 70 per cent. multiplied by the ratio of the sectional area of the rail to the enclosing rectangle, thus proves true in the two preceding, as it has in hundreds of other, instances tested by the author. In some recent examples, the bottom table of the rail is narrower than the top, the form of cross section approaching in fact to that of a T iron; and it is necessary to remark that the increase in such instances will be found equal to 70 per cent. multiplied by the ratio of the rectangle, formed by the width of the bottom table and the height of the rail, to the sectional area of the portion of rail enclosed in this rectangle. For a pure T section this of course would be equal to 70 per cent. multiplied by one, or, in other words, the increase would be the same as in a rectangular bar.

The following extreme case is selected for illustration of the practical sufficiency of the above empirical rule:

c. A built "channel" beam having a $6\frac{1}{4}$ inches $\times \frac{3}{8}$ inch web plate, and two angles $2\frac{3}{4}$ inches $\times$ $2\frac{3}{4}$ inches $\times \frac{5}{16}$, made of steel having a specified tensile strength of from 27 tons to 31 tons per square inch, is tested, web plate uppermost, at 3-feet bearings; required the weight applied at the center which this beam would support without permanent set.

The elastic strength of the steel would probably range from about 15 tons per square inch to 10 per cent. above that amount. Cutting out a template of the beam in drawing paper, and suspending it, to find the center of gravity, and otherwise proceeding as in the instance of the rails, the "effective depth" is found to be 2.1 inches, the "effective flange area" 0.76 inch, and the moment of resistance $= 2.1 \times 0.76 = 1.60$.

A distinct permanent set in this instance, according to the theory advanced, would not be produced until the apparent tensile strain in the vertical webs of the angle-irons was equal to, from 15 tons $\times$ $(1+70$ per cent.$) = 25.5$ tons per square inch, to 10 per cent. above that, or 28 tons per square inch, which is not far from the ultimate direct tensile strength of the steel.

The equivalent load in cwts., (W) applied at the center of 36-inches bearings, will be:

$$W = \frac{25.5 \text{ tons} \times 20 \times 1.6 \times 4}{36'} = 90.6 \text{ cwts.}$$

With an apparent strain of 28 tons per square inch the value of W would be 99.6 cwts.

The weight indicated by calculation as that which the described beam would support, without appreciable set, may thus fairly be stated as from 90 to 100 cwts.

Referring to the "rigidity tests" in Mr. Martell's paper on "Steel for Shipbuilding,"* from which the above example was taken, the following will be found to be the results of direct experiment:

Between 0 and 90 cwts.
permanent set = 00009 inch per cwt.
Between 90 and 100 cwts.
permanent set = .00500 inch per cwt.

In this extreme case, therefore, calculation and experiment are in accord, as in both instances the required weight is found to be from 90 to 100 cwts.

In another experiment the angles were brought together back to back and riveted to the plate, thus making a built-up T beam, which was tested table

* Trans. Inst. Naval Architects, vol. xix., p. 20.

downwards at 36-inches bearings, with the result as before of showing a practical accordance between the theoretical and actual elastic strength.

The former beam may be looked upon as an exaggerated example of a rail with no bottom flange, and the latter, as that of a rail with wide bottom flange and no head; hence it is no matter for surprise that the method of calculation advanced gives satisfactory results in the instance of rails of every variety of cross section met with in practice. An extension of the method to rolled joists, deck beams and built girders of every description is equally admissible, if it be clearly borne in mind that at stresses above the elastic limit a beam may, and often does, fail from local weakness before the resistance of the metal has been fairly developed.

From many hundreds of experiments on beams of every variety of cross section, the author has been led to the conclusion that the elastic strength of a beam represents some 50 to 55 per cent. of the ultimate strength which will be developed, if the beam is free from local weakness. In the instance of rolled joists and built girders, the local weaknesses determining failure are generally narrowness of flange and thinness of web. A top flange may be made very narrow, if the bottom flange is wide and the web thick, as already instanced in the case of the inverted T-beam, and as will be further illustrated by the following example of an iron-flanged rail:

d. A flanged rail 4.56 inches deep by 5 inches wide at the foot, and $2\frac{1}{2}$ inches wide at the head, weighing 73 lbs. per yard, is made of iron having an ultimate tensile strength of 25 tons per square inch; required the ultimate strength at 48-inches bearings, assuming that the failure does not occur by the apparent local weakness of the relatively narrow top flange in compression.

Here the area of the rail = 7.3 square inches; the center of gravity = 2.14 inches from the bottom, and 2.42 inches from the top; the "effective depth" = 3.61 inches; the "effective area" = 2.28 square inches; the moment of resistance in compression = 8.23, and in tension = 9.3; and the ratio of the area of the rail to the enclosing rectangle = 0.32. The ultimate direct tensile strength of 25 tons per square inch, would be increased to 25 tons $\times$ (1 + 0.32 $\times$ 70 per cent.) = 30.5 tons per square inch, under transverse stress; and the ultimate load (W) would thus be:

$$W = \frac{9.3 \times 30.5 \times 4}{48} = 23.6 \text{ tons.}$$

The preceding rail was one of a series tested for the author, and was returned as having an elastic strength of 11.6 tons, and an ultimate strength, under a deflection of 3.38 inches in the 4-feet span, of 23.7 tons.

The "apparent" compressive strain upon the head of the rail under this load would be 34.5 tons per square inch, hence the fair ultimate strength of about double the elastic strength was fully developed, notwithstanding the narrowness of the top flange of this beam.

In the above case, the relatively great width of the bottom flange, and the thickness of the web, compensated for the narrowness of the top flange, or the result would have been very different, as will be seen from the following typical example of the behavior of a rolled joist under transverse stress:

e. A rolled joist 12 inches $\times$ $\frac{5}{8}$ inch $\times$ 6 inches $\times$ $\frac{3}{4}$ inch, weighing 56 lbs. per foot, is made of iron, having an ultimate tensile strength of 24 tons per square inch; required the elastic transverse strength at a span of 20 feet.

Here the area of joist = 16.8 square inches, the moment of resistance = 63.6, and the ratio of the area of the joist to the enclosing rectangle = 0.23. In the fibrous iron of which joists are made, the maximum increase is generally 60 instead of 70 per cent.; hence, taking the elastic tensile strength at 50 per cent. of the ultimate, or 12 tons per square inch, the "apparent" elastic tensile strength under transverse stress will be, 12 tons $\times$ (1 + 0.23 $\times$ 60 per cent.) = 13.7 tons per square inch, and the required load at the center of 20-feet span will be:

$$W = \frac{63.6 \times 13.7 \times 4}{20 \times 12} = 14.5 \text{ tons.}$$

By direct experiment the load proved to be 14.7 tons at the elastic limit; but in this instance, owing to the narrowness of flange, the full resisting power of the metal was never even approached, or the ultimate load supported would

have been about double the above, or 29 tons, instead of the 19.2 tons actually obtained. In fact, owing to lateral weakness, the joint behaved as joists usually do, and failed by lateral flexure under a calculated unit strain only one-third greater than the strain at the elastic limit, instead of at, or about, double the latter, as in the instance of the iron rail, and other examples, where the full power of the metal w s developed.

A beam may also fail through lateral flexure of the web, as instanced in the following examples of some riveted girders of the same span as the above, which the author had manufactured to elucidate this and other disputed points:

f. A riveted girder with a 24 inches × ½ inch web, and with five 8 inches × ½ inch plates, and two 3 inches × 3 inches × ½ inch angle-irons in each flange, is made of iron having an ultimate tensile strength of 21 tons per square inch, and an elastic strength of 50 per cent.; required the weight which would be supported at the center of 20-feet bearings without appreciable permanent set.

Here the moment of resistance in compression = 610, and in tension through the rivet holes = 432. Taking the mean of these = 521 as the effective moment in determining the point at which an appreciable set would occur—having reference to the fact of the plates being riveted, and not welded together, and for the latter reason also taking the increased strength under transverse stress as proportional to the minimum cross section of the girder (where there is only one 8 inches × ½ inch plate in the flange) and the enclosing rectangle; then the 10.5 tons per square inch elastic strength will become

$$10.5 \text{ tons} \times \left(1 + \frac{25.5 \text{ sq. in.} \times 60 \text{ per cent.}}{25'' \times 8''}\right)$$

$=11.3$ tons, and the required load will be

$$W = \frac{521 \times 11.3 \times 4}{20 \times 12} = 98 \text{ tons};$$

which was the result obtained by the author by direct experiment.

It is not contended, of course, that the correction for the increased strength under transverse stress is of any practical moment in the instance of ordinary riveted girders; but it is introduced here rather with a view of showing that the correction does not conflict with experimental results even in the extreme case cited.

g. A riveted girder identical with the preceding, with the exception that the bottom flange was made of eight 5½ inches × ½ inch plates, and two 2½ inches × 2½ inches × ½ inch angle-irons, was similarly tested at 20-feet bearings, and failed by distortion under a load of 102 tons; required the tensile and compressive strains under that load.

Here the moment of resistance in compression was 630, and in tension 450; hence the required unit strains will be:

$$\frac{102 \text{ tons} \times 20 \times 12}{630 \times 4} = 9.7 \text{ tons}$$

per square inch compression:

$$\frac{102 \text{ tons} \times 20 \times 12}{450 \times 4} = 13.6 \text{ tons}$$

per square inch tension.

The previous experiment *f*, proved that the effective elastic strength of the flange in compression was at least as much as 9.7 tons per square inch, so this is a case in which failure occurred at, or below, the elastic limit, as far as the top flange was concerned. That the failure was not due primarily to the narrowness of the top flange is apparent at once, from the relatively high resistance of the joist at the same span, though the flange was narrower in the ratio of 6 inches to 8 inches.

A tabulation of the results obtained in experiments *d*, *e*, *g*, with some others, will render this still more apparent.

	Ratio of Span to Width.	Ultimate "Apparent" Compressive Strain.
d (iron rail)	20	34.5 tons per sq. in.
e (" joist)	40	18.2 " " "
g (" girder)	30	9.7 " " "
h (" joist)	48	17 9 " " "
i (" ")	30	18.8 " " "

Experiment *h* refers to some joists 10 inches × 5 inches tested by the author at 20-feet spans, and *i*, to some joists 12 inches × 6 inches tested at 15-feet spans.

It is clear, therefore, that the failure of girder *g* was not due to narrowness of flange, but to the relative lightness of the web. The latter was much stiffer

than usual, as it was $\frac{1}{2}$ inch thick, in one length without joint, and stiffened every 5 feet with two 3 inches × 3 inches × $\frac{1}{2}$ inch angle-irons and two 5 inches × $\frac{1}{2}$ inch packing-strips under the same. Nevertheless, it did not suffice to maintain the rectangular connection of the several parts of the girder, and failure occurred by lateral flexure of the web at one end of the girder under a "shearing strain" of but 42½ tons per square inch.

This experiment is sufficient to enforce upon the attention of engineers the fact that width of flange is not necessarily an efficient substitute for rigidity in the connections of the main girders of a bridge. The author in continental bridges has frequently employed flange-bars only 10 inches wide for lattice-girders of 66-feet span—a ratio of about 80 to 1; and in girders over 200-feet span he has been satisfied with a ratio of less than 110 to 1; but then the whole structure has been so rigidly connected together by gussets and bracing, that the top flange has had no more chance of evading its work than the head of the rail had in experiment *d*.

Two sources of local weakness, namely, deficient lateral stiffness of flange, and want of rigidity in the web and its connections, have now been illustrated; but there are others existent which would no less vitiate the results deduced from any general theory of transverse stress, and of these the most important is the following:

The strength of a plate web, according to Professor Airy, M. Bresse, and nearly every other mathematician, is governed by the resistance of the web to the diagonal compression due to the shearing stress. This may be practically true in some few instances, but it was not so in that of the 24 inches × ½ inch web of girder *g*, or the shearing strain sustained would have been double the 4½ tons per square inch, which crippled the web; neither was it even approximately true in the instance of some girders with 3 feet 6 inches × ¼ inch webs, which the author tested with the view of determining the real nature of the stresses in a plate girder as ordinarily constructed. These girders *k* were 31 feet 8 inches effective span, and the ¼ inch web was in five lengths of 6 feet 4 inches × 3 feet 6 inches plate, riveted together by T-iron stiffners 5 inches × 4 inches × $\frac{3}{8}$ inch, having stiffner-plates ¼ inch thick, and edge L-irons 2½ inches × 2½ inches × $\frac{5}{16}$ inch. The top flange was 20 inches wide by ½ inch, with edge L-irons 4 inches × 4 inches × ½ inch. The bottom flange was 20 inches × ¾ inch; and both top and bottom flanges were secured to the web by 4½ inches × 4½ × ½ inch L-irons. The effective area of the flange in tension was 19 square inches, and in compression 26 square inches; so that, having reference to the width of flange, in all probability, the girder tested to destruction would have failed by tension, unless the web first failed. The author determined to test the elastic strength of the web of these girders. From previous experiments on similar girders with webs of double the thickness, he knew that, so far as the flanges were concerned, appreciable permanent set would not be exhibited until the tensile strain on the bottom flange exceeded 10 tons per square inch; and when, therefore, under a load of 70 tons, a slight set appeared, which at 75 tons had increased to more than $\frac{1}{16}$ inch, he knew that the set was wholly due to the web, because the unit strain on the flanges corresponding to the load of 75 tons was but 8.6 tons per square inch in tension and 6.25 tons in compression.

This load was applied opposite a stiffner, at a point distant 12 feet 8 inches and 19 feet from the respective abutments, and the maximum "shearing force," therefore, would be 45 tons, or at the rate of 4.3 tons per square inch on the gross section of the web. The resistance of the thin web to diagonal compression would be less than a third of this, so the strength was obviously not governed by the conditions laid down in the ordinary theory. The permanent set of $\frac{1}{16}$ inch could not be due to excessive compressive strains on the web, because the total deflection of the girder was far too small to permanently bend such an elastic long column as that constituted by the ¼-inch web. It could only be due, therefore, to the stretching of the web under the diagonal tensile strains; and the lines of greatest severity of strain from the bottom of one vertical stiffener to the tops of the adjoining ones were plainly marked by an apparent buckling of the web along

those lines, when the girder was subjected to the stated load. From a careful consideration of the phenomena exhibited, the author was led to the conclusion that at a point in the center of the 6 feet 4 inches × 3 feet 6 inches web plate, where, by the ordinary theory, the diagonal strains would be about $4\frac{1}{2}$ tons per square inch both in tension and compression, the strains were as a matter of fact about 11 or 12 tons in tension, and half a ton, or a ton in compression. Rankine has shown how little the change of form in a plate web conduces to the total deflection of a girder; and, for similar reasons, a set of $\frac{1}{16}$ inch from web strains indicates very clearly the severity of the strains.

The author verified his experiments on the preceding girder by numerous others on five girders of equal size, but with varying proportions of flange and web, and obtained practically identical results. He also made models of the girders to scale, with wooden flanges and stiffeners, and paper webs. Testing these little girders to destruction, the lines of stress were indicated with conspicuous clearness; and the phenomena exhibited by the full-sized girders were exhibited also, in an exaggerated degree, by the models. Indeed, the latter experiments proved more suggestive than all the experiments on the iron girders, and all the mathematical investigations on the subject; and, after witnessing them, there was no difficulty in forming a clear idea of the nature and intensity of the strains occurring in a plate web as ordinarily constructed.

The local weakness in the preceding girders, which would have determined failure before the full strength of the flanges had been developed, was again thinness of web. In the three cases cited—the rolled joist, the 24 inches girder, and the 3 feet 6 inches girder—the strengthening of the locally weak portions would be a subject rather for practical experience than theoretical investigation. Many such cases are met with in practice, the minimum strength which must be provided in the bracing of the struts of lattice-girders being one such. So far as plate webs of medium size are concerned, the author is of opinion that the general conditions laid down by Mr. Chanute in his specifications for the Erie Railroad bridges, meet all the requirements indicated by experiment, and he cites these in preference to his own practice as being independently deduced. These are, that the "shearing strain" shall not exceed half that allowed in tension on the bottom flange of a riveted girder, and that when the least thickness of the web is less than $\frac{1}{80}$ of the depth of the girder, the web shall be stiffened at intervals not over twice the depth of the girder.

If judgment be exercised in the design of girders so as to avoid local weaknesses, then, according to the author's experience, the method of investigation which has been found to give trustworthy results in the instance of iron and steel rails will give equally trustworthy results in the instance of every other description of iron and steel beam.

The anomalies presented by beams of different cross sections, as regards strength, do not extend to their deflections except that, as already stated, the elastic range is increased.

The elastic deflection δ of a beam of any type, but of uniform cross section, of the depth d and span s, will for a central load be given by the following equation:

$$\delta = \frac{s^2 f E}{6d},$$

when f is the mean of the "apparent" maximum tensile and compressive strains upon the metal in tons per square inch, and E, the modulus of elasticity expressed by the extension or compression, in terms of the length, for each ton per square inch strain. For a uniform load, the divisor will become $\frac{2}{3}4$, instead of 6; and for a girder of uniform depth and uniform strain per square inch, however loaded, the divisor will be 4.

The value of E varies considerably, even in the same length of rail or plate; but, as the result of many experiments, the author adopts the following average values:

For iron beams, E=.000085 to .00010.
For steel beams, E=.000075 to .00009.

At working strains the value approximates more nearly to the smaller, and at strains near the elastic limit to the larger figures.

In the case of built girders, the calcu-

lated and experimental results compare best when the depth d is taken between the flanges, and not from outside to outside; and where the web is thin the value of E may be taken at .00012. Although the author has on several occasions tested built girders beyond the elastic limit, without detecting the slightest movement of rivets and plates, it is only reasonable to conclude that the riveted structure must be a trifle less rigid than a solid beam.

The variation in the value of the modulus is a matter which has not yet received sufficient consideration from engineers. In built girders the practical effect of this variation no doubt is, that whilst a uniform strain, say of 5 tons per square inch, is assumed to be acting on the flange, the real strain on the several plates may range almost from 4 tons to 6 tons per square inch. Mr. Bender, and other American engineers, have found the moduli of eye bars to vary considerably with the cross section;* and other experiments also indicate the advisability of building up the flanges of girders with plates of uniform size, as well as quality.

Although, on the average, a steel rail or beam will be found stiffer than an iron one of the same cross section, this will not be true of every individual specimen. Thus, in some recent experiments, conducted for the author by Professor Kennedy, M. Inst. C.E., the moduli determind with great exactness for one piece of steel, and two pieces of iron rail of the same cross section proved at low strains to be respectively .000086, .000078, and .000089.

Frequent reference has been made to the terms "elastic limit" and "permanent set;" and it is necessary to explain what is understood by those expressions in the present paper.

If deflections or extensions be noted in a microscopic manner, permanent set will be apparent under comparatively low strains; but if the sets are plotted as ordinates to a curve, it will be found that, at a certain point more or less defined, the curve sharpens in radius, and in some cases diverges almost at right angles. The occurrence of this curve of course marks the attainment of the elastic limit; but different observers would only by chance agree as to the exact point of commencement, and hence the differences which often arise as to the elastic limit. In the case of hardened steel the curvature is very gentle: in that of soft iron, a sudden flow of metal often makes the bend almost rectangular. In cases where there is doubt as to the fair position of the limit, the author draws tangents to the deflection curve at points corresponding respectively to, say 40 per cent. and 60 per cent. of the estimated ultimate load, and takes the intersection of those tangents as marking the position. Except in the case of hardened steel, the elastic resistance considered in this broad practical sense will be generally found, both in iron and steel, to be equal to from 50 to 55 per cent. of the ultimate tensile resistance of the material.

In conclusion, the author would remark that the experiments detailed in this paper are but unselected samples of many hundreds, in which the same accord between calculated and experimental results is exhibited.

A word of caution is necessary to students: firstly, that differences of 4 or 5 per cent. between calculated and experimental results are suggestive of nothing, because different pieces of rail rolled from the same bloom or ingot exhibit that variation; and secondly, that in investigations of this sort it is absolutely essential to reject all tests made by unskilled persons. A single example will suffice: an iron rail which the author calculated would exhibit an elastic strength at 5-feet bearings of 9.5 tons, and a practical ultimate strength of about 19 tons, was returned, firstly by the manufacturers, and afterwards by the author's inspector, as exhibiting the strength and deflection set forth in the first line of the following table, whereas the true experimental results were those given in the second line:

Deflection Inches	¼	1¼	2¼	3	4	4¾
Weight in tons. {	14	24	34	40	43	48
	9.3	14.7	16.0	16.8	17.6	19 0

The results of the first line were con-

* Trans. American Society of Civil Engineers, vol. v. (1876), p. 147. "Continuous Girders," by C. Bender.

firmed by further experiments after the attention of the manufacturers and inspector had been called to the matter, and they adhered to their returns in perfect good faith.

By following the method of calculation indicated in this paper, the author, during the past fifteen years, has found no difficulty in specifying the strength which a rail should exhibit under the lever test, when made of steel or iron of the desired tensile strength; and much time and labor have been saved in dispensing with the planning out and testing of pieces under direct pull.

At the same time it is a practical convenience to be enabled to specify with exactness the tests for a new and untried section of rail. Thus, a few months ago (the fact is worthy of record for more reasons than one), a contractor offered to substitute steel for iron, without extra charge, in some 5,000 tons of flange rails he was delivering; and, as the rails had holes in the flanges, the author especially desired to secure steel of uniform and relatively soft quality. He specified, therefore, that the rails, when loaded with a weight of 20 tons at the center of 3 feet 6 inches span, should exhibit a permanent set not less than $\frac{1}{32}$ inch, nor more than $\frac{6}{32}$ inch. The test was arrived at as follows: the moment of resistance of the 70-lbs. rail was 8.75; the ratio of increased tensile strength under transverse stress 1.22; and, as the desired maximum direct tensile strength of the steel was 37 tons, with an elastic limit of 53 per cent., the maximum elastic transverse strength, at 42-inches bearings, would be

$$\frac{37 \text{ tons} \times 1.22 \times 53 \text{ per cent.} \times 8.75 \times 4}{42 \text{ inches}} = 19.9 \text{ tons.}$$

A set of at least $\frac{1}{32}$ inch under a load of 20 tons would, therefore, ensure the steel being not more than 37 tons per square inch in tensile strength. But it was also necessary to define a test for the lower limit of its strength, fixed at 33 tons per square inch. Under the load of 20 tons the strain upon steel of this strength would be the following percentage of the ultimate strength:

$$\frac{20 \text{ tons} \times 42 \text{ inches}}{33 \text{ tons} \times 1.22 \times 8.75 \times 4} = 60 \text{ per cent.}$$

Now the author knew from previous experiments that, within certain limits, a rail at 42-inches bearings takes a set of about $\frac{1}{32}$ inch for each 1 per cent. strain beyond the elastic limit; hence, as the elastic limit in the above instance is assumed to be at 53 per cent., the set at 60 per cent. would be about $\frac{7}{32}$ inch, or say $\frac{1}{4}$ inch. The specified sets of $\frac{1}{32}$ inch to $\frac{1}{4}$ inch would, therefore, correspond to steel having a direct tensile strength not less than 33 tons, nor more than 37 tons. It only remains to add, that the rails as manufactured complied with these tests, and that the direct tensile strength of a strip planed from the bottom flange of one of the stiffest specimens was 36.7 tons per square inch

As regards the possibility of substituting for the practical experience now indispensable in a designer, a general theory of transverse strength, universally applicable and wholly satisfactory from a scientific point of view, the author is not at all sanguine. A careful observation of the behavior of structures of every class under stress has satisfied him that sooner or latter, in every instance, a stage in the investigation is arrived at where the general theory becomes valuless, and even dangerous, except in the hands of the experienced engineer. At the same time the purport of this paper will be entirely misconceived if it is understood to reflect in any way upon the importance of direct experiment and strict mathematical investigation, of the value of which no one can be more alive than the author.

Herr Bottger has recently described a metallurgical use for glucose, and says that there is no method for reducing the salts of silver so convenient and so sure as that by glucose in alkaline solution. Take, for example, chloride of silver freshly precipitated and well washed, suspend it in a sufficient quantity of diluted caustic soda, and add a small portion of glucose; in a few minutes, upon boiling, the reduction takes place. The silver can be collected, washed and slightly calcined, in order to obtain the metal pure, under the form of a light sponge of a dull white. The same method furnishes an exceedingly active platinum black.

THE AREA OF THE SQUARE DEGREE

By FRANK D. Y. CARPENTER, C. E.

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IN finding the area of a large portion of the earth's surface, as, for example, the territory of the United States, it is best to consider this surface as an aggregation of quadrilaterals bounded by meridians and parallels, the extent of each of which is one degree in latitude by one degree in longitude. Each of these blocks may be called, for the sake of convenience, a "square degree." All of these square degrees lying in an east and west series across the country have the same area. It is, therefore, only necessary to determine the contents of a tier extending north and south between the extreme latitudinal limits of the country which is to be treated.

If the earth were a perfect sphere it would be an easy matter to find the area of the square degree.

The area of the sphere is represented by the formula

$$4\pi R^2.$$

Of the spherical zone, being derived from that of the sphere,

$$4\pi R^2 \sin.\ \tfrac{1}{2}(L'-L)\cos.\ \tfrac{1}{2}(L'+L)$$

And of the spherical quadrilateral, being a definite portion of the zone,

$$\frac{\pi}{90}(M'-M)R^2 \sin\tfrac{1}{2}(L'-L)\cos\tfrac{1}{2}(L'+L),$$

in which R is the radius of the sphere, and M', M, and L', L, are the boundary meridians and parallels of the quadrilateral.

To adapt this formula for the spherical quadrilateral to the spheroidal surface of the earth some geographers, accustomed to the frequent substitution of the normal for the radius in their geodetic and astronomical operations, have attempted to make the normal for the mean latitude, $\frac{L'+L}{2}$, do the same duty in this case. This application is erroneous, and it is to demonstrate its falsity and to provide a correct formula, that this note is prepared.

To find, then, the contents of a square degree upon the earth's surface, the following course may be pursued:

Take the length in meters or yards of the radius of curvature of the meridian, Rm, at the middle latitude $\frac{L'+L}{2}$, of this area, and consider it as the radius of a new and perfect reference sphere, to whose conditions this square degree shall be adapted, and by whose formula its area shall be determined. From the meridional arcs to be found in all geodetic tables take the latitudinal extent, $L'-L$, of the square degree under consideration; also, from the radius of the reference sphere, compute its circumference and thence the length of one degree of latitude, which, since this is a perfect sphere, will be $\frac{1}{360}$ of the great circle. It will be found that these degrees of latitude on sphere and spheroid are practically equal.

Now take the extent in longitude of the square degree, measured in meters along its middle parallel, and apply it along the same parallel of the reference sphere. It will be found to exceed a degree in length upon the latter, for the circumference of any parallel upon the earth's surface is a function of the radius of this parallel, and this radius is found by the formula

$$Rp = N\cos.\ L,$$

while, upon the reference sphere,

$$Rp = R\cos.\ L.$$

But R is the radius of curvature of the earth's meridian, and this is constantly smaller than the normal for the same latitude. Therefore, one of the earth's parallels is larger than the corresponding parallel on the reference sphere, and, in proportion, one of the earth's degrees of longitude is longer than a corresponding degree on the same. It is for this reason that the formula for the sphere cannot be adapted to the spheroid by the substitution of the radius of curvature for the radius, a step which, at first glance, might seem feasible.

A square degree upon the earth is thus shown to be equal to an extent of one degree in latitude by one degree and

some seconds in longitude on the new sphere, and, with these data and the radius of this sphere, its area can be now determined by the formula for the spherical quadrilateral.

In this method the earth's meridian, as far as included, is supposed to have the constant curvature of its middle point; it may therefore be advisable, to avoid error, to restrict this solution to areas not exceeding a square degree in extent.

To illustrate the preceding process, let us take any square degree lying between parallels 37° and 38° of latitude.

The radius of curvature of the earths' meridian for the middle latitude 37° 30′ is 6358420 meters.

The length of a degree upon a reference sphere with this distance as a radius is 110975.4 meters. The length of meridional arc from 37° to 38° latitude on the earth is 110975 meters. Observe the agreement. It is to be expected, however, when it is remembered that a degree of latitude upon the earth is a length of arc limited, not by two radii, but by two normals which intersect at the approximate center of curvature of the arc, and hence at a distance from the surface equal to the radius of curvature.

The length of a degree of longitude measured along parallel 37° 30′ on the earth is 88420 meters. The same, on parallel 37° 30′ of the new sphere, is 88042.7 meters. That is, one degree upon the earth equals 1° 00′ 15″.43 or 1°.004285 on the reference sphere.

A quadrilateral of 1° in latitude by 1°.004285 in longitude between parallels 37° and 38° of a sphere whose radius is 6358420 meters, comprises an extent of 3788.55 square miles. This is the area of the square degree aforesaid. Calculated by the current but erroneous formula. it would be 3804.49 square miles. The error of the latter, as will be seen, is 15.94 square miles, and, continued in the same proportion throughout the United States it would give a result wrong by many thousands of square miles. It will be interesting to note, in the revised areas about to be published as one of the results of the tenth census, how serious a misconception we have hitherto had upon this subject.

It now remains for us to arrange the results of this discussion in the concise shape of a formula. To do this it is only necessary to find some expression for the value of a degree of the earth's longitude in terms of corresponding degrees upon the reference sphere.

The length of a degree upon the earth is

$$\tfrac{1}{360}.\ 2\pi \mathrm{N}.\ \cos.\ \mathrm{L}.$$

On the new sphere it is

$$\tfrac{1}{360}.\ 2\pi \mathrm{R}m\ \cos.\ \mathrm{L}.$$

Therefore one degree on the spheroid is equal to $\frac{\mathrm{N}}{\mathrm{R}m}$ degrees on the sphere, and $\mathrm{M}'-\mathrm{M}$ degrees on the former equal $(\mathrm{M}'-\mathrm{M})\frac{\mathrm{N}}{\mathrm{R}m}$ degrees on the latter. Substituting now in the formula for the spherical quadrilateral, we have, for the area of a similar figure on the spheroid,

$$\frac{\pi}{90}(\mathrm{M}'-\mathrm{M})\frac{\mathrm{N}}{\mathrm{R}m}.\mathrm{R}m^2.\ \sin.\ \tfrac{1}{2}(\mathrm{L}'-\mathrm{L})\cos.\ \tfrac{1}{2}(\mathrm{L}'+\mathrm{L})$$

Or,

$$\frac{\pi}{90}(\mathrm{M}'-\mathrm{M})\,\mathrm{N}.\,\mathrm{R}m.\ \sin.\ \tfrac{1}{2}(\mathrm{L}'-\mathrm{L})\ \cos.\ \tfrac{1}{2}(\mathrm{L}'+\mathrm{L}).$$

That is, for the square of the radius of the sphere we substitute the product of the radius of curvature of the meridian by the normal, which is the radius of curvature of the great circle perpendicular to the meridian, these two radii being taken at the middle latitude of the area to be treated.

The foregoing is an illustration of the extra labor and annoyance imposed upon the mathematician by what he comes at last to consider as the imperfect manner in which the universe is put together. If the earth were only a perfect sphere; if the pole star were really at the pole; if the magnetic needle pointed to the north, or, indeed, were constant in any direction; if the earth's axis were perpendicular to its orbit plane; if the moon were more straightforward in her course and the sun less irregular in his comings and goings; if the stars were placed in regular order instead of being sown broadcast; and if the famed circle of heavenly motion did not so often degenerate into an ellipse, the laborious processes of astronomical and geographical computation would be very much simplified, certainty would take the place of approximation in their results, and they would become exact sciences indeed.

ON PIN CONNECTIONS FOR IRON BRIDGES.

By Dr. E. WINKLER.

Translated from the "Deutsche Bauzeitung" of August 14, 1880, by G. F. Swain, S. B.

The chief advantage of the system of pin connections for iron bridges, almost universally used now in America, is claimed to be the possibility of a more exact determination of the stress in each piece, and partly in a reduction of the stress itself. It is, however, frequently forgotten that the hinges are never perfect, that is, that they never permit an absolutely unhindered rotation, on account of the fact that a tendency to rotation calls into play the friction of the pin, the effect of which increases with the size of the pin. Nevertheless, very large pins have sometimes been projected; for example, one of the projects submitted for the Schinkel competition of the Society of Engineers and Architects of Berlin in 1879, provided for pins in the upper chord over 28 inches in diameter (.72 meters); and in the *Journal of the Austrian Society of Engineers and Architects* for 1880, p. 127, is published a project in which some of the lower chord pins are equal in diameter to the height of the chord.

In order to examine this point, let us first ask what diameter the pin must at least have, in order that a rotation may be just prevented, so that in this case the pin connection acts exactly as a riveted one would.

If ρ is the radius of curvature of the originally straight axis of a girder, M the moment acting in any cross section, E the coefficient of elasticity, I the moment of inertia of the whole section about its neutral axis, then if we neglect the influence of the deformation of the web members we have, as is well known,

$$\frac{1}{\rho}=\frac{M}{EI}.$$

The effect of the deformation of the web members is to increase this value by an amount which may be nearly 40%, and we will therefore put

$$\frac{1}{\rho}=a\,\frac{M}{EI} \quad . \quad . \quad . \quad . \quad . \quad (1);$$

a being a coefficient greater than 1. A more exact investigation could easily be made, but we prefer at present the above approximate formula.

If m denotes the moment which acts on one of the chords itself (causing it to bend between two joints), and i the moment of inerta of the chord section, then we shall also have (the joints being supposed incapable of permitting a rotation)

$$\frac{1}{\rho}=\frac{m}{Ei}\,;\quad m=\frac{Ei}{\rho},$$

and substituting the value of ρ from (1)

$$m=\frac{ai}{I}\,M \quad . \quad . \quad . \quad . \quad . \quad (2)$$

If S is the stress in the chord considered, h the height of the girder, then in general we have approximately, and exactly in the case of straight chords $M=Sh$, and hence

$$m=\frac{ai}{I}\,Sh \quad . \quad . \quad . \quad . \quad (3)$$

The pressure of the chord on the pin is also S. Hence if f is the coefficient of sliding friction, and d the diameter of the pin, the friction will cause a moment equal to m, or will balance m, when $m=Sf\frac{d}{2}$. Hence we must put, in order to find the necessary diameter of pin,

$$\frac{ai}{I}\,Sh=Sf\frac{d}{2}$$

and

$$d=\frac{2aih}{If} \quad . \quad . \quad . \quad . \quad (4)$$

If F is the cross section of the chord, and r its radius of gyration, we have

$$I=\tfrac{1}{2}Fh^2 : i=Fr^2$$

hence

$$d=\frac{4ar^2}{fh} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

If the section of the chord is a rectangle, as in the lower chords of American bridges, and if the breadth is b and the

height c, we have $F=bc$; $i=\frac{1}{12}\ bc^3$; $r^2=\frac{i}{F}=\frac{1}{12}c^2$, hence

$$d=\frac{ac^2}{3fh} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

If we assume $a=1.25$: $f=0.15$, we have

$$d=2,8\,\frac{c}{h}.\,c \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and even if the pins were lubricated, and f became as small as 0, 08, we should have

$$d=5,2\,\frac{c}{h}.\,c \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

As this diameter is always smaller than the diameter of the pins in use in America, we can conclude that the pin joints as a rule do not act like hinges at all. The most favorable chord section is the one with the largest moment of inertia, but even in the most favorable case r^2 is at most equal to $\frac{1}{6}\,c^2$, and hence d is twice as large as in the previous case. Even here it appears scarcely possible to make the pin so small that they shall not prevent rotation. The cross-shaped chord section, for which pin connections have very lately been used by Gerber, in Munich, appears still more unfavorable than the rectangular section.

If the diameter of the pin is made smaller than is necessary to insure equilibrium between the moment of the friction and m, a rotation will occur; but the bars will bend until a state of equilibrium between the two moments arises. If the diameter is made only $\frac{1}{n}$th of that determined by the previous investigation, there will still exist in the bars a bending moment equal to $\frac{1}{n}$ th of that which would exist were the connections riveted.

It may be assumed, probably, that in consequence of shocks and vibrations, a certain rotation will nevertheless occur, so that gradually a state of things comes to exist in which the separate bars, under the dead load alone, remain straight, and possess the stresses determined by the theory supposing the joints hinged. But this is not true as regards the live load.

In regard to the web members, the investigation is more difficult than in the case of the chords, which we have hitherto been considering. The equations (5) and (6) may be considered as approximate in this case, if r and c refer to the section of the web member. Hence the web members would generally require still smaller pins to connect them with the chords than the chords require for connection with each other.

ON THE USE OF ASPHALT AND MINERAL BITUMEN IN ENGINEERING.

By WILLIAM HENRY DELANO, Assoc. Inst. C.E.

From Minutes of Proceedings of the Institution of Civil Engineers.

I.

In the year 1876 the author translated for the Institution a memoir by M. Ernest Chabrier, civil engineer, "On the Applications of Asphalt." This paper, and the well-known work of M. Léon Malo on the same subject, are exhaustive as regards the general question.

The object of the present communication is to give a description of certain executed works, with their cost, an account of various failures that have been overcome, and such information concerning the quality and preparation of the material as will enable a supervising agent to insure good work and discover fraud. The author's personal experience is confined to France, particularly Paris, where he has been engaged since 1871 in the practical application of natural asphaltic compounds, and where the use of the material has obtained a position as one of the great industries of the country.

It is important that M. Malo's nomenclature should be adhered to in specifications. 1st. Asphalt is a natural pro-

duct, a bituminous limestone, consisting of carbonate of lime and mineral bitumen, intimately combined by natural agency. 2nd. Asphalt mastic is the rock ground to powder and mixed with a certain proportion of bitumen similar to that originally contained in the rock. 3rd. Gritted asphalt mastic is asphalt mastic to which washed or river sand, free from all earthy matters, has been added. 4th. Asphaltic or bituminous concrete is gritted asphalt mastic in a hot state, mixed with dry flint or other stone. 5th. Bitumen is a mineral product found in asphalt rock, in Trinidad and in other places. According to Boussingault, bitumen is composed of

Carbon	85	parts.
Hydrogen	12	"
Gxygen	3	"
	100	

It is therefore an oxygenated hydrocarburet. It is not gas tar, nor Stockholm tar, neither is it pitch from suets and fatty matters, or from shale or petroleum.

The asphalts that have come under the author's observation are those of Val de Travers, Seyssel, Sicily, Chieti in the Abruzzi, Auvergne, Lobsann, and Limmer. Analyses of various asphalts by M. Hervé Mangon and M. Durand-Claye, of the Laboratory of the Ecole des Ponts et Chaussées, Paris, are given in Appendix A.

The engineer who is specifying asphalt for roadways, footpaths, waterproof coatings for arches, vaults, casemates, &c., may test the material thus: A specimen of the rock, freed from all extraneous matter, having been pulverized as finely as possible should be dissolved in sulphuret of carbon, turpentine, ether, or benzine, placed in a glass vessel and stirred with a glass rod. A dark solution will result, from which will be precipitated the pulverized limestone. The solution of bitumen should then be poured off. The dissolvent speedily evaporates, leaving the constituent parts of the asphalt, each of which should be weighed, so as to determine the exact proportion. The bitumen should be heated in a lead bath and tested with a porcelain or Baumé thermometer to 428° Fahrenheit. There will be little loss by evaporation if the bitumen is good, but if bituminous oil is present the loss will be considerable. Gritted mastic should be heated to 450° Fahrenheit. The limestone should next be examined. If the powder is white, and soft to the touch, it is a good component part of asphalt, but if rough and dirty, on being tested with reagents, it will be found to contain iron pyrites, silicates, clay, &c. Some asphalts also are of a spongy or hygrometrical nature. Thus, as an analyses which merely gives so much bitumen and so much limestone may mislead, it is necessary to know the quality of the limestone and of the bitumen.

For a good compressed roadway, an asphalt composed of pure limestone and 9 to 10 per cent. of bitumen, non-evaporative at 428° Fahrenheit, is the most suitable. Asphalts containing much more than 10 per cent. of bitumen get soft in summer and wavy; those containing much less have not sufficient bind for heavy traffic, although asphalt containing 7 per cent. of bitumen, properly heated, does well for courtyards, as it sets hard when cold.

Asphaltic rocks, rich in bituminous matter, generally contain volatile oils. In the author's opinion it is not safe to specify any asphalts for roadways that have not withstood at least three cold winters and three hot summers.

Trinidad bitumen is now largely used to mix with asphalt powder for mastic. In the raw state it contains from 40 to 45 per cent. of dirt, and 35 per cent. of water. It is refined by mixing with it about one-third its weight of schist or shale-grease (*i. e.*, the pitch remaining after the lighting and lubricating oils have been exhaled in distillation), and heating the mixture for twenty hours, after which it is passed through a fine colander and decanted. The theory is that the shale grease and water are evaporated, the earthy matters precipitated, and the other extraneous matters screened out. There is always a residue, however, of about 20 per cent. of fine clay in purified Trinidad bitumen, and sometimes much more. In testing, the easiest way is to dissolve the bitumen in sulphuret of carbon, and to strain the solution through thick blotting paper, which retains and gives the proportion of the clay, which should not exceed 20

per cent.; afterwards using the evaporative test already described.

ROADWAYS OF COMPRESSED ASPHALT.

It may be taken for granted that the use of asphalt roadways is now approved in England. The various reports of Mr. William Haywood, M. Inst. C. E., are conclusive on this point. No roadway is perfect; but the author is of opinion that, for cities with heavy traffic, and where the gradients do not exceed 1 in 50, a well laid surface of compressed asphalt is near perfection. It is noiseless, does not vibrate, produces neither dust nor mud, is cheap and durable, easily repaired, and the old material can be used again. The best foundation is a bed of Portland cement concrete, 6 to 9 inches thick, with as little floating as possible, laid on a resisting subsoil. The surface of compressed asphalt powder should be from 2 to 2½ inches thick. The present price of a compressed asphalt roadway per square meter is, in Paris, for ordinary traffic:

	Frs.	Cts.
Portland cement concrete, 6 inches thick	5	25
Compressed asphalt, Seyssel or Val de Travers, 2 inches thick	14	15
	19	40

or, say, about 13s. per square yard. But the distance from the mines influences the cost of the material.

The first asphalt roadway laid by the author was in the Rue d'Antin, Paris, in 1872. With the exception of a piece cut off for the New Opera avenue, it has stood perfectly well to the present time. It replaced a causeway of granite sets, and one-half the expense was paid by the landlords of the street. As the engineers of the city were only able to specify a layer of 4 inches of hydraulic lime concrete, the extra cost of laying the 2 additional inches of concrete and the Portland cement was paid by the Compagnie Générale des Asphaltes de France, who had contracted to maintain for six years the roadways and footpaths in compressed asphalt and mastic. On each side of the roadway were placed gutters of Belgian granite sets, 16 by 20 centimeters and 60 centimeters wide, with cement-mortar joints, and a fall towards the curb of 1 in 28. This was done by order of M. Alphand, Director of Works of Paris, who had noticed that the greasy water, which runs from the houses into the gutters, in streets where there are no drains, rotted the asphalt, and that the consequent repairs were difficult owing to the habit of flushing the gutters with pure water several times a day. This difficulty does not exist in streets where there are drains.

In laying the concrete, the screeds were set so that there should be a fall on each side of the crown of the roadway of 1 in 50. The average width of the roadway was 17.7 feet, and the longitudinal fall about 1 in 100. The asphalt powder was ground fine in a Carr's disintegrator, heated in a yard 1½ miles distant to 284° Fahr., carefully spread over the dry concrete, and rammed with hot rammers till the surface became resonant.

Appendix B gives a tabulated statement of the works executed by the author, with the nature of foundations, and observations as to duration.

Among the difficulties the contractor has to contend with in laying an asphalt causeway are the prejudices of the foremen, who prefer tradition to reason. The tradition is that sand is incompressible; that sand makes a good foundation for granite sets, and therefore does equally well for concrete. Sand is incompressible in a cylinder, but under street traffic gets displaced, and absorbs water, causing the concrete to crack. The layer of compressed asphalt follows, and then unsatisfactory repairs are made, for repairs on a shifting concrete, through which the wet can rise, never last long. The author, when executing such repairs in winter, had the surface sprinkled with dry cement, afterwards rammed, and then a layer of liquid asphalt run over it and allowed to cool, so as to have a dry surface on which to lay the hot powder.

When superseding granite sets by asphalt, the sand should be removed, and the concrete laid on the hard soil; for, just as hard granite sets require an elastic foundation, so does the slightly elastic surface of compressed asphalt require a rigid foundation. In preparing the foundation of the asphalt roadways of the Place de l'Europe and the Auteuil bridges, Paris, a coating of liquid asphalt ⅝ inch thick was first laid down to

keep out the surface water from the masonry, then a 3-inch bed of sand by order of the Government engineer, who feared lest the immediate contact of the rough concrete with the asphalt mastic would damage this coating. On the top of the sand was put a layer of 4 inches of hydraulic lime concrete, and on the top of the concrete 2 inches of compressed Val de Travers asphalt. The contracting company had agreed to keep these roadways in order during six years for one franc per square meter per annum. The cost to the contractors was about ten francs per squares meter per annum. The rain water filtered through the curbstone into the layer of sand; in hard winters it froze, and forced up the concrete, and in summer the sand yielded under heavy traffic, causing depressions in the surface. The author, finding the contract most onerous, proposed to the engineers of the city of Paris to lay the whole work afresh upon their paying only for one-half of the new concrete, and using up the sand for mortar. This offer was refused. Since the termination of the six years' contract the two bridges have been in worse order than ever; that at Auteuil is now nearly all macadam on one side; the Pont de l'Europe is honeycombed also in holes and lumps.

Experience has proved that hydraulic lime concretes are of little use for asphalted roadways; they do not set quickly enough for crowded cities, and are never dry, as is shown by the fact that, whenever an opening is made to a gas or a water pipe, the old lime concrete is found to be wet. In 1877 the author laid the Pont Masséna, Paris, a railway viaduct, for M. Barabant, municipal engineer; but on the liquid asphalt coating, Portland cement concrete 9 inches thick was laid, and on the concrete a layer of $2\frac{1}{4}$ inches of Val de Travers compressed asphalt. This work has never moved, and may last from fifteen to twenty years, in spite of heavy goods traffic. In 1872 the author inherited a ten years' contract for the maintenance of the asphalt roadway of Elbeuf bridge, covering 1,400 superficial meters. This structure is of wrought iron, subjected to considerable vibration under traffic. The flooring is of Mallet's buckle-plates, covered with hydraulic lime concrete, with a layer of 2 inches of compressed asphalt superposed. Owing to the shape of the buckle-plates the concrete was of unequal thickness. The maintenance of the roadway under these conditions cost 10,000 francs per annum, whilst the sum paid by the Department of the Seine Inférieure was 1,400 francs, or one franc per square meter per annum. The lime concrete broke up under the vibration, and the asphalt of course followed. As the repairs were continuous, application was made to the authorities to be relieved of the contract upon payment of an indemnity. The authorities declined. They had tried wood, which wore out; granite sets were too heavy; macadam was too expensive. To meet the difficulty of the vibration, it was resolved to replace the hydraulic lime concrete with bituminous or asphaltic concrete. The roadway was accordingly taken up, the old compressed asphalt was heated till it fell to powder; it was then mixed with refined bitumen to make it into mastic, to which 40 per cent. of dry grit was added, and with every 2 parts of this asphaltic mortar, 3 of hot flint stone were mixed. This concrete was laid down hot upon the buckle plates, and well rammed and dressed till a hard and slightly elastic surface was obtained. Upon this surface a layer 2 inches thick of compressed Val de Travers asphalt was put down. This work was finished in October, 1875. Up to August, 1879, not a single repair had made, though the traffic had much increased. In the Rue de Sèvres, in 1876, the author replaced a roadway of granite sets by compressed asphalt, in front of the Hospital Necker and the Institution of the Infant Blind, and resolved to replace the hydraulic lime concrete specified by natural or Roman cements. The result was not satisfactory; the concrete crumbled under the heavy traffic, and a portion of the work had to be relaid.

From the foregoing it appears that, for asphalt, good foundations of Portland cement concrete must be laid not less than 6 inches thick, but a layer of 9 inches is better. Lime and Roman cement concretes should never be specified for heavy traffic. Bituminous concrete cost, say, £4 per cubic yard, and is too expensive for ordinary work, though

invaluable in special cases. There is some difficulty in getting thoroughly burnt and finely ground Portland cement. Fraudulent mixing is practised, and marked casks are refilled with an inferior article.

The asphalt powder cannot be too fine. If it could be got like the stive dust in flour mills, or, as the French workmen say, "folle farine," it would be perfection. In heating it care must be taken to evaporate all the volatile bituminous oils. To this end the powder heaters should be open at each extremity and the powder well stirred. Great care must be taken that no wood, or foreign object, gets mixed with the powder, as it will cause a hole sooner or later. Sometimes, after three or four years, a chip of hard wood will work its way up through a layer of 2½ inches of asphalt under traffic. The author in 1876 laid down a road in the Rue de Vaugirard with great care; a month afterwards there was a hole in the middle. Upon examination it was found that one of the workmen had left in the concrete his wooden screed, which had rotted. Mr. Edwin Chadwick, C. B., who has studied asphalt under the hygienic aspect, has designed an asphalt tramway for ordinary carriages, which should answer well, as asphalt properly laid is more durable than granite flags or iron rails.

Asphalt is not slippery *per se*, but it becomes so if a coating of greasy mud is allowed to remain upon it. Roadways of asphalt, from the same mines as used in London, are laid in Paris, and the complaint of slipperiness does not arise. This immunity is not the result of a drier atmosphere, as some have supposed, but simply that in the latter city the roadways are regularly swept and washed, whereas in London they are not.

The dampness of the atmosphere has an important bearing upon the question of the best material for carriageways in towns, and the author has been at some pains to obtain trustworthy information on this subject. He hopes to establish the fact, that the alleged greater dampness of the air in London against that of Paris is to some extent imaginary, and that it is to want of scavenging alone that the slipperiness of asphalt roadways in London is attributable. By the kindness of M. Mascart, director of the Bureau Central Météorologique, he is able to give authentic figures showing the humidity in Paris for six years ending 1878. The values of London are taken from the quarterly returns of the meteorology of England, published by authority of the Registrar-General.

TABLE OF SEASONAL HUMIDITY.

Saturation = 100.

Paris (Saint Maur).	1873.	1874.	1875.	1876.	1877.	1878.
Winter.....	86.6	88.5	87.6	89.5	86.2	88.3
Spring.....	75.0	71.8	66.4	69.9	76.8	77.0
Summer....	78.7	67.8	77.3	69.6	75.1	78.7
Autumn....	87.3	85.1	85.0	87.9	83.7	85.6
Means.....	81.9	78.3	79.1	79.2	80.4	82.4

London (Greenwich).	1873.	1874.	1875*	1876.	1877.	1878.
Jan—March	86.0	84.0	80.0	85.0	83.0	84.0
April—June.	78.0	76.0	88.0	75.0	73.0	79.0
July—Sept..	77.0	77.0	81.0	74.0	76.0	79.0
Oct.—Dec...	88.0	88.0	85.0	83.0	84.0	85.0
Means.....	82.2	81.25	84.6	79.2	79.0	81.75

The means for the six years are, therefore, for Paris, 80.2; London, 81.5—a difference of dampness insufficient to exercise any appreciable influence.

In a paper published in the "Annales des Ponts et Chaussées,"† M. Vaissière, Chief Engineer, gives the total cost of the scavenging service in Paris as £195,000 per annum. This includes scraping, sweeping, and washing the streets, watering in summer, and clearing away ordinary snowfalls in winter. The author has not access to the London Vestries, but he doubts if in the aggregate they spend much less in order to obtain a result which in comparison is wholly inadequate. In any case, in view of the advantages to the senses and health of the inhabitants, and the immense saving in the money value of goods now spoilt by mud and dust, he ventures to assert that an efficient system of scavenging similar to that of

* Heavy rain-storms in Spring and Summer.

† *Vide* Minutes of Proceedings Inst. C.E., vol. 1, p. 223.

Paris would be cheaply obtained if its adoption cost five times the amount quoted above.

In asphalted streets, where no provision exists for washing the roadways by flushing from the hydrants, an arrangement has been devised which is found to be economical and easy of application. The apparatus consists of a wrought-iron or wooden cart-body, mounted on four wheels, of which the two front ones swivel freely, and are drawn by two stout horses. Under the shaft runs a jointed pipe, with a perforated delivery tube, set at right angles, and which can be raised or lowered by means of a rack. This delivers a shower of water in front of the horses, which help by their tread to liquify the mud. The plan is adopted in Piacenza and other towns of Northern Italy, and is attended with no inconvenience to the horses, or otherwise. Behind the horses is a second distributor, which further dilutes the sticky mud, followed by an adjustable broom. Behind the broom is a third delivery pipe, followed by an adjustable revolving cylinder, set obliquely, and carrying a combination of bass brooms and "squeegees." The oblique set causes the diluted mud to be at once swept into the gutter. The capacity of the cart is 600 gallons, the three pipes distribute together two gallons per second, but this quantity can be regulated according to the state of the mud. Supposing the horses to walk at the rate of 6 feet per second, the tank will be emptied in five minutes.

The cost of this apparatus complete is taken at £70.

	£	s.	d.
The interest and maintenance at 15 per cent. per annum would be per day	0	0	7
Wages of two men at 4s.	0	8	0
Two horses and harness	1	0	0
Total per day	1	9	7

Or say for two machines, £3 per day.

Adopting the figures given in Sir Joseph Whitworth's paper on street cleansing:*

	£	s.	d.
One machine would do the work of 17 men (sweepers) at 4s per day	3	8	0
Cart horse and driver	0	16	0
Total per day	4	4	0

* *Vide* Minutes of Proceedings Inst. C.E., vol. vi., p. 431.

Or for two sets £8 8s., as against £3 for the two washing and sweeping machines. Further, taking Sir Joseph Whitworth's estimate of 14,000 square yards per day, the then cost of cleansing a length of street of 60 yards, and, say 20 yards wide, would be 2s. 7d.; but it is fair to assume that a greater surface of smooth asphalt could be cleansed in the same time than of ordinary macadam.

The scavenging of Paris costs 2½s. per square meter per annum, or say 2d. per square yard. A comparison between the two asphalted streets of Rue de Richelieu in Paris, and Cheapside, London, in muddy weather, shows the advantage of the Paris system of scavenging. Horses in Paris slip on the hard granite sets; they do not slip on asphalt more than on macadam, and on a level road start easily when loaded.

Compressed asphalt is not affected by heat, except that it becomes slightly soft, but without losing its ring under the horses' hoofs, and extreme frost has no effect upon it; but in case of any cracks or holes they will get gradually enlarged under the action of repeated wet thaws. It is easy to clear snow off asphalt, much more so than off any other paving.

The author has used asphalt bricks and cubes for paving; but even under the most favorable circumstances the employment of powder is preferable. It is not easy to effect repairs in asphalt sets from the fact that, when under traffic, compression is going on, and the new sets, not having the same density as the old, rise above them and so get chipped.

Compressed asphalt gives no spark when struck, which makes it valuable for the floors of powder magazines, cartridge manufactories, &c. The French Artillery have used it for this purpose at the School of Pyrotechny at Bourges, and at the Donjon of Vincennes, and the Military Engineers have employed it at the fort of Génicourt, near Verdun.

Compressed asphalt is used in gateways like those of the Place du Carrousel, and the Place des Vosges, Paris, to absorb vibration and thus to prevent the destruction of architectural ornaments, &c.

The extent of surface of compressed

asphalt in the public streets of Paris is 309,000 square meters—or 370,000 square yards—not taking into account the numerous courtyards, gateways, and passages for private use.

QUALITIES OF VARIOUS ASPHALTS.

With regard to the quality of the various asphaltic rocks, the author submits the following opinion: Val de Travers rock is sure to give a satisfactory result if properly ground, heated, and laid on a good foundation. It is, however, sometimes too rich in bitumen, in which case it must be heated longer and well stirred, to get rid of the volatile bituminous oils. An admixture of 25 per cent. of old Val de Travers compressed asphalt, cleaned, grnund up and passed through the pulverizing machine simultaneously with the new rock, so as to get thoroughly mixed, is of advantage with rich asphalt; but it is not advisable to mix two asphalts from different mines, as for instance, Val de Travers and Seyssel. Such mixtures will last for two, three, or even four years, and then break up, at least this has been the author's experience in the Rue de Richelieu. Seyssel rock contains less bitumen than Val de Travers, and the limestone being harder and of finer grain is frequently unimpregnated; for these reasons Seyssel rock should be broken in pieces and hand-picked before grinding. The author has laid many streets in Paris in Seyssel asphalt, and always uses it for courtyards. In spite of the comparatively small proportion of bitumen, this rock will bear a good heating. The bitumen is not of an easily evaporative character. Sicilian rock, from Ragusa, is a coarse-grained spongy limestone of unequal impregnation. The bitumen is of a very volatile character. This rock is no longer included in the list of those specified by the Paris engineers. Auvergne rock contains a large proportion of excellent bitumen, but the impregnated stone is more of a grit, or sandstone, than limestone. A trial was made in the Rue du Faubourg Poissonniere, in the year 1877, and the road lasted just three months. The asphalt was compressed cold with a 30-ton steam roller, having been previously sprinkled with volatile shale oil. Auvergne mastic is coarse and sets soft. Maestu rock has been used successfully for mastic, but utterly failed when laid in 1871 in London, in the shape of bricks compressed cold. Chieti rock is exceedingly rich in good bitumen, but has not been successfully used for compressed purposes in France. It makes very coarse mastic. Lobsann rock is of a mixed character, containing a large proportion of good bitumen and bituminous oils. It has been used exclusively in Paris since January, 1878. The winter of 1878–9 was eminently unfavorable to this rock. Some new work, laid on cement foundations, and where there is little traffic, has stood fairly, but time is required to test it. If it breaks up within three years it is of little use as a contractor's material. In Paris this rock, owing to its richness in bitumen, is mixed with one-third poor asphaltic rock ground fine.

MASTIC ASPHALT.

The surface of footpaths in mastic asphalt in Paris alone, is 3,150,000 square meters—or nearly 4,000,000 square yards; and when the courtyards, cellars, &c., are counted it is considered that double the surface exists.

The Paris engineers have made it a rule that the thickness of the layer of gritted mastic should be 15 millimeters, or $\frac{3}{5}$ inch, and a lime concrete 10 centimeters, or 4 inches thick, of which 2 centimeters, or $\frac{1}{16}$ inch, are mortar floated to keep the surface level. One fifteenth part has to be laid fresh annually. The contractor is paid for this and all the repairs besides (*i. e.*, to keep the work in order) a fixed sum of 35 centimes per meter, or 2½d. per square yard per annum; the openings for gas and water pipes being paid for separately. Each system must be judged by its result. In Lyons, and in other towns of France, where repairs are paid for by the square meter, and the thickness of the asphaltic layer is $\frac{3}{16}$ inch, the work is well done, whereas in Paris the footpaths seldom look well. In fact, the engineer, knowing that a fresh fifteenth has to be laid every year, thinks that he will comprise therein all the bad work: and the contractor does not care to do good work because he may in the following year have to relay the new work as fifteenth part, owing to changes

of level, &c. Again, in this system of a limited sum paid per yard per annum for an unlimited quantity of repairs, one of the contracting parties must get an unfair advantage.

CONCRETE FOR FOOTPATHS.

In the author's opinion, a layer of four inches of hydraulic lime concrete on a firm soil is a good foundation for mastic asphalt; or for the same purpose 3 inches of Portland cement concrete may be employed. Roman cement should never be used in concretes for mastic asphalt, nor stone lime. Both cause bubbles and blisters, which eventually produce holes. Mortar floating should be used sparingly to fill up interstices in the concrete, and to form a level surface, and should be spread before the concrete is dry. A thick layer of mortar serves to cover bad concrete, but not to make a good foundation. One of the chief causes of cracks and depressions in the compressed asphalt roadways of Paris is from spreading a thick layer of mortar over the concrete, which crumbles under the traffic, and indeed under the iron rammers during the compression of the powder. A favorite fraud of the dishonest contractor is to cheat in the thickness of the concrete, nor does he neglect to carry out the same idea with the asphalt. In 1872 the author found a considerable portion of the concrete of the Rue de Richelieu $2\frac{3}{4}$ to 3 inches thick, instead of 4 inches, and the subsoil loose (the work had been let out to the workmen by the piece), whilst some footpaths in front of the Hotel de Ville were not laid with concrete at all, but a little mortar had been spread on the bare earth. Asphalt in itself has no more power of resistance to vertical pressure than sheet lead or india-rubber; therefore it must yield unless well supported from beneath.

MANUFACTURE OF ASPHALT MASTIC.

The rock must be ground into fine powder, all coarse grains being sifted out, returned to the disintegrator and reground. After being mixed with the bitumen, as described, it must be well worked, *i. e.*, the bitumen must be thoroughly incorporated with the asphalt, and an amalgam made capable of being ground again into powder. The quantity of bitumen to be added depends upon the amount contained in the rock, but 15 per cent. of the total weight is what mastic should hold when run in blocks. It is sufficiently tested when a wooden spatula can be put into the mass and withdrawn without adherence. Mastic made from fine-ground powder, when remelted, pure, or unmixed, spreads out under the wooden stave or spatula used by the asphalters for the covering of vaults, fillets, &c., and will absorb the maximum of grit when used for footpaths, stables, courtyards, &c.

MASTIC ASPHALT IN MILITARY ENGINEERING.

In the many large new forts constructed in France since 1871 pure mastic asphalt has been extensively used for covering the roofs of vaults, casemates, and powder magazines, with very satisfactory results; as when the inevitable settlements of the new masonary happens, the asphalt yields without cracking, whereas cement cracks and lets the water into the joints of the masonry, causing damp in the casemates and bad health to the garrison. The most recent practice is to lay pure mastic asphalt $\frac{5}{8}$ inch thick in two layers. When applied vertically for chimneys and air shafts a recess is cut in the masonry, into which the asphalt is run, so that the water passes over to the gutters or drains. The flooring of the casemates is laid with gritted mastic. The troops in garrison have sometimes complained of the asphalt flooring being damp. It is certain that it is non-absorbent, and therefore the condensed moisture remains visible and must be mopped up or swept away. The flooring of powder magazines is in pure mastic, over which, in some cases, wood planking, fastened with copper nails, is laid.

GROUTING FOR GRANITE SETS.

This work, which is charged in the Paris Architects' Price-book for sets, say 6 inches by 10 inches and 2 inches deep of mastic, costs about 2s. $11\frac{1}{2}$d. per superficial yard, whereas in gas tar and chalk the cost is only 1s. $8\frac{1}{2}$d. Mr. G. F. Deacon, M. Inst. C. E., has shown the inconvenience of using inferior materials for grouting. It is good policy to use natural asphalt mastic for this work. The interest on the increased cost is less

than the cost of renewels, to say nothing of the annoyance to traffic caused by frequent repairs. This grouting is particularly useful in courtyards and stables; it prevents the effluvium from all ordinary joints, which, with the subjacent layer of sand, soon become filled with horse-dung and other filth. It also holds the sets together, prevents the edges wearing, and lessons the noise whilst improving the appearance. Natural asphalt can be melted again and again with the admixture of fresh purified bitumen, without losing its qualities. In some grouting recently carried out in front of the terminal station of the Eastern railway in Paris, the joints are run too deep to keep the horse urine out, but it cannot percolate to the subsoil. Asphalt grouting should always be laid in dry weather, and the joints well rammed, so as not to use more mastic than necessary.

VERTICAL APPLICATION OF ASPHALT MASTIC.

This is a development of the fillet generally employed in all horizontal applications, and to keep out damp and moisture; the height is mostly $3\frac{1}{2}$ feet to 4 feet. The price paid in Paris is about 4s. per superficial yard $\frac{1}{8}$ inch thick. The mastic is pure, and is laid on in two layers, one workman following the other as closely as possible, using the mastic very hot and pressing it hard. The powder magazines in the Cherbourg forts have been recently so treated; also the chimneys and air shafts of the casemates of the Paris forts. The advantages of the employment of asphalt under such circumstances are that, should there be a settlement of the masonry, it does not crack like cement. In case of leakage, the removal of 40 feet of earth is costly, and as old cement cannot be used over again, it has to be carted away.

BITUMINOUS OR ASPHALT CONCRETE.

In 1872 the proprietor of a factory for painting on glass and china, threatened to take proceedings against the author for damages caused by the vibration of a Carr's disintegrator, running at 500 revolutions per minute, used in pulverizing asphalt in the factory of the compagnie Générale des Asphaltes. This vibration also interfered with the counting-house work of the Company's clerks, and, in fact, when the machine was running the ground shook within a radius of 25 yards. The old foundations in wood and masonry were therefore replaced by bituminous concrete, as were also the walls and the bottom of the pit on which the disintegrator works. This succeeded so well that it is now impossible to know from the vibration when the disintegrator is at work, and there have never been any yielding, settlement, or repairs, since it was laid. Subsequently, the author put down a foundation for a large steam press for stamping out iron frames, and striking twelve blows per minute. Also one at the Artillery Factory in the Donjon, at Vincennes, under the orders of Captain Naquet, for a small steam hammer, and for the factories of the Paris, Lyons, and Mediterranean railway, under the orders of the Engineer-in-chief Duboys, and other similar works. At the Paris Exhibition of 1878, a block of this material, weighing 45 tons, was used as a foundation for a Carr's disintegrator for grinding flour, running at 1,400 revolutions per minute.

IMITATION ASPHALT.

There are two kinds of imitation asphalt: 1st. A mixture of ground limestone, ground slate, and Trinidad bitumen, which, if properly made, is as dear, or dearer, than the real article, without being one-half as good. 2nd. A mixture of ground chalk, fire-clay, and gas tar, which is frequently passed off as real asphalt. The author's experience of this material is that it becomes soft in summer and cracks in winter, and should never be used for footpaths, or where there are great changes of temperature. The Paris engineers, after repeated trials on account of its cheapness, have proscribed its use. This mixture is readily recognized by its dull, black appearance, its characteristic smell, and the hard metallic sound it gives when struck against iron in cold weather. The unpopularity of asphalt with many engineers and architects arises from their having had work done with preparations of gas tar improperly called asphalt. Some contractors substitute shale grease or pitch from suets, or Stockholm tar, for bitumen. The result is a soft surface for the first year, which gives off

oils by evaporation, and breaks up after two or three years' wear; whereas asphalt properly laid on a good foundation will wear down evenly until little more than a film remains.

The tricks of the small Paris contractors are many. They keep a little natural asphalt and bitumen beside their boilers for show, all the while using gas tar and chalk, so that when the work breaks up the superintendent is frequently ready to affirm that asphalt was used, and declares for ever after that asphalt is of no use.

INGOT IRON.

From "The Engineer."

It has become so difficult to say what is the difference between Bessemer metal and wrought iron that for some time past engineers and metallurgists, alike, have freqently substitued the words "ingot iron" for "steel," and there can be no possible objection to the change in terminology; indeed, it is very much to be commended. The word "steel" ought to be confined to the product of the crucible or the cementing furnace, which always possesses characteristics which mark it out clearly and unmistakably from any form of iron. While, however, it is certain that ingot iron resembles very closely iron made in the puddling furnace instead of the converter or the open hearth, it is also certain that it possesses some characteristics which are very different from any manifested by iron, and of these and of their nature it is essential that all makers and users of ingot iron should take note. Steel came to us after iron; and the qualities of steel are all estimated and pronounced good or bad by comparison with iron. Lowmoor, for example, and Bowling are taken as standards, and we hear it said a given steel is as "tough as Lowmoor," or that "it works like Bowling." In the course of years Lowmoor and Bowling—indeed, the best Yorkshire irons generally—have been brought up to a high degree of excellence, if excellence be supposed to consist in complying with the demands made by engineers for special qualities in the plates they work. Thus it has been found to be good practice to flange boiler plates, instead of using angle iron to connect them, and Lowmoor and Bowling plates have accordingly been made which will flange perfectly. Then steel plates were produced, with the same object in view, and with more or less success. Although it is convenient to call what has been for a long time known as "steel," ingot iron, and although it is also convenient to compare ingot iron with ordinary iron, we must not go too far, and assume that the two materials are practically the same for constructive purposes. On the contrary, there are very wide differences between them, and is just as well that these differences should not be overlooked even for a moment.

The great peculiarity about ingot iron is that for some reason, not yet understood, certain impurities affect it more than wrought iron; and that it is also very easy to set up in it intense initial strains, which never seem to exist in wrought iron. It is very well known that Lowmoor and Bowling plates are by no means absolutely perfect and it is probable that of late years the metal is not so good as it used to be. Be this as it may, plates from Yorkshire are now and then found to be very bad indeed. This fact is freely used by the advocates of steel. Thus, when a steel plate fails, they will ask, "Well, does an iron plate never give way?" This is a very good argument up to a certain point; but it must not be pushed too far. No one contends that the so-called perfect iron plates do not fail now and then; but a very little experience suffices to show that they do not fail in quite the same way as steel plates. It is not, in truth, the failures of ingot iron, but the manner of failure, which exerts the most malign influence on the future of the metal. To explain what we mean we may cite the case of a boiler-plate of steel which is flanged all round—say a back plate for a locomotive boiler. This plate is completed, put on one side for the night, and in the morning it is found that the flange has come away from the

plate everywhere. Here we have, in the first place, all the labor which has been expended on the plate wasted; but far worse than this, we have an element of doubt and uncertainty introduced which is prejudicial in the extreme to steel. If a plate leaves the flange while lying quietly in a yard, who is to say whether, should a second and similar plate be worked into a locomotive, it may not leave the flange when steam is up and with the most disastrous effect? This is a very serious question indeed for those who have much responsibility, as, for example, locomotive superintendents. It will be said, and truly said, that Lowmoor plates will now and then part company with a flange. We admit this; but there is no instance on record of Lowmoor giving way like steel. The defect in the Yorkshire iron would manifest itself almost from the first; and a crack would be found between the flange and the plate before the metal was cold. In one word, if wrought iron will bear the ordeal of being worked into shape, it may be relied on to support heavy strains. But when we come to deal with ingot iron there is apparently a risk that when work is complete it will, as in the case of the Livadia's boilers, tumble to pieces before it is put to use; or that having been put to use it will fail without a moment's warning. About the worst defect that Lowmoor or Bowling plates will manifest is a tendency to blister—very vexatious and annoying, but not very dangerous. Let us imagine that the Livadia's boilers had just withstood the 150 lbs. water test and had gone to sea; will any one, knowing what we now know concerning them, assert that the boilers would not have been more dangerous than if they had been made of good tough cast iron? To put this more plainly, the new shells are to be made, if they have not yet been made, of steel supplied by the Steel Company of Scotland. What is the security that this metal will be better than that which failed? Samples will bear specified tests; but so did the steel supplied by Messrs. Cammell. When we come to dive below the surface of things, it will be seen that there is no security at all that the new boilers will not behave like the old boilers, save the eminent reputation of the steel company of Scotland. But surely it must be admitted that this is a state of affairs quite without parallel as regards iron. Wrought iron has a reputation of its own; but steel at present, and possibly for a long time to come, has no reputation, and depends for its popularity as a constructive material on the reputation of those who make it. Let it not be forgotten that while both wrought iron and ingot iron are liable to fail, the characteristics of these failures are entirely different. The failures of steel are almost always treacherous; those of iron honest and above board. Leaving out blisters, when an iron plate fails, it fails under the smith's hammer. If it be possible to make a boiler shell of Yorkshire iron, we may rest certain that boiler shell is a good one, and that if it be tested to 150 lbs. it will carry 75 lbs. per square inch with safety. But we have no certainty that if we make an ingot iron shell that shell will be a good one; on the contrary it may crack here, there, and everywhere, and even though it withstands 150 lbs. it by no means follows that it will be quite safe when worked at half that pressure. If the plates come from a given firm the chances are all that the boiler will stand; but if the plates come from another firm, it is quite possible that it will not stand, and this uncertainty exists although every known means of satisfying ourselves that the metal is good, save that of buying the metal in a certain place or from certain firms, has been tried with perfect results.

To assert that these things are not so, or that we draw an exaggerated picture is worse than useless. We happen to know that the history of the failures, which have attended attempts to introduce and to adopt steel as a constructive material, will never be written. It is a sealed book to the general public. We have already explained that those who use steel and find it wanting hold their tongues. Those who make steel are equally desirous to say nothing about their failures. This policy of reticence is to be deplored. Ingot iron is to be the constructive material of the future. In a very few years boilers, ships, everything will be made of it; but a good deal has to be learned first concerning the mode of making it, and the mode of using it to the best advantage. Failures

are as instructive as successes, and more so in this case; and publicity should be courted rather than discouraged. It is no shame to an engineer that a steel boiler has failed; it is no disgrace to the makers of the plates that they have not turned out well; but it is, above and beyond all else in this connection, essential that we should know all about the idiosyncracies of steel or ingot iron. We could easily name many points on which research is required. For example: why is it that local strains may, and undoubtedly do, exist in steel which do not exist in iron? A plate of wrought iron may be found which will bear 25 tons on the square inch tensile strain, and which may be bent and contorted in all sorts of ways, and yet will not break. Holes may be punched in it, and its edges may be sheared without weakening it. An apparently similar steel plate, also with a tensile strength, say, for example, of 25 tons to the inch, and seemingly even more ductile, will crack a few hours after it has been handled, and may be rendered worthless by punching a couple of holes in it, or by shearing the edges. Chemically these plates will be to all appearance nearly identical, why then do the two behave so dissimilarly? It would seem that the answer is to be sought in the method of manufacture. Ingot iron is practically free from cinder, but the very best Lowmoor is not. The molecular arrangement of the steel plate is not fibrous like that of the wrought iron, but either amorphous or crystalline. What part does fiber play? Is it not possible that it distributes strains, carrying them across fixed lines of demarcation? May it not be that fiber acts somewhat as a calico lining to a postal envelope, to use a crude simile, and so toughen more than it strengthens? The great difference between the fracture of a pane of glass—illustrating brittleness—and that of a piece of whalebone—illustrating toughness—is that the line of fracture of the one is definite and precise and in planes, while that of the other is irregular and diffused, and the area of surface separated is, other things being equal, much greater in the one than in the other. Even microscopical fibers may play a very important part indeed in the economy of steel, and much may be learned from an examination of the surfaces of fractured plates, both of wrought iron and ingot iron, which will be of future use. If it can be shown that the best ingot iron for constructive purposes is that which shows most indications of the presence of fiber in its composition, a great deal will have been gained. Chemistry has, too, something yet to learn and to teach us. Amongst other things, why small quantities of sulphur phosphorus and silicon should affect ingot iron far more prejudicially than they affect wrought iron as made in the puddling furnace. It has been said, for example, that the steel of the Livadia's boilers contained 0.09 per cent. of silicon. We have good reason to doubt the accuracy of this statement; but, supposing it to be true, it is quite certain that wrought iron plates containing that amount of the impurity would not have behaved as did the ingot iron of which the Livadia's boilers were made. Why?

PROFESSOR KIRCHOFF ON LIGHTNING RODS.

THE city gas company of Berlin, having expressed the fear that gas pipes may be injured by lightning passing down a rod that is connected with the pipes, Professor Kirchhoff has published the following reply: "As the erection of lightning rods is older than the system of gas and water pipes as they now exist in nearly all large cities, we find scarcely anything in early literature in regard to connecting the earth end of lightning rods with these metallic pipes, and in modern times most manufacturers of lightning rods, when putting them up, pay no attention to pipes in or near the building that is to be protected." Kirchhoff is of the opinion, supported by the views of a series of professional authorities, that the frequent recent cases of injury from lightning to buildings that had been protected for years by their rods, are due to a neglect of

these large masses of metal. The Nicolai Church, in Griefswald, has been frequently struck by lightning, but was protected from injury by its rods. In 1876, however, lightning struck the tower and set it on fire. A few weeks before the church had had gas pipes put in it. No one seems to have thought that the new masses of metal which had been brought into the church could have any effect on the course of the lightning, otherwise the lightning rods would have been connected with the gas pipes, or the earth connection been prolonged to proximity with the pipe. A similar circumstance occurred in the Nicolai Church in Stralsund. The lightning destroyed the rod in many places, although it received several strokes in 1856, and conducted them safely to the earth. Here, too, the cause of injury was in the neglect of the gas pipes, which were first laid in the neighborhood of the church in 1859, shortly before the lightning struck it. The injury done to the schoolhouse in Elmshorn, in 1876, and on the St. Lawrence Church, at Itzehoe, in 1877, both buildings being provided with rods, could have been avoided if the rods had been connected with the adjacent gas pipes.

"If it were possible," says Kirchhoff, "to make the earth connection so large that the resistance which the electric current meets with when it leaves the metallic conducting surface of the rod to enter the moist earth, or earth water, would be zero, then it would be unnecessary to connect the rods with the gas and water pipes. We are not able, even at an immense expense, to make the earth connections so large as to compete with the conducting power of metallic gas and water pipes, the total length of which is frequently many miles, and the surface in contact with the moist earth is thousands of square miles. Hence the electric current prefers for its discharge the extensive net of the system of pipes to that of the earth connection of the rods, and this alone is the cause of the lightning leaving its own conductor."

Regarding the fear that gas and water pipes could be injured, the author says:

"I know of no case where lightning was destroyed a gas or water pipe which was connected with the lightning rod, but I do know cases already in which the pipes were destroyed by lightning because they were not connected with it. In May, 1809, lightning struck the rod on Count Von Seefeld's castle, and sprang from it to a small water pipe, which was about 80 meters from the end of the rod, and burst it. Another case happened in Basel, July 9, 1849. In a violent shower one stroke of lightning followed the rod on a house down into the earth, then jumped from it to a city water pipe, a meter distant, made of cast iron. It destroyed several lengths of pipe, which were packed at the joints with pitch and hemp. A third case, which was related to me by Professor Helmholtz, occurred last year in Gratz. Then, too, the lightning left the rod and sprang over to the city gas pipes; even a gas explosion is said to have resulted. In all three cases the rods were not connected with the pipes. If they had been connected the mechanical effect of lightning on the metallic pipes would have been null in the first and third cases, and in the second the damage would have been slight. If the water pipes in Basel had been joined with lead instead of pitch, no mechanical effect could have been produced. The mechanical effect of an electrical discharge is greatest where the electric fluid springs from one body to another. The wider this jump the more powerful is the mechanical effect. The electrical discharge of a thunder cloud upon the point of a lightning rod may melt or bend it, while the rod itself remains uninjured. If the conductor, however, is insufficient to receive and carry off the charge of electricity, it will leap from the conductor to another body. Where the lightning leaves the conductor its mechanical effect is again exerted, so that the rod is torn, melted, or bent. So, too, is that spot of the body on which it leaps. In the examples above given it was a lead pipe in the first place, a gas pipe in the last case, to which the lightning leaped when it left the rod, and which were destroyed. Such injuries to water and gas pipes near lightning rods must certainly be quite frequent. It would be desirable to bring them to light, so as to obtain proof that it is more advantageous, both for the rods and the buildings which they protect, as well as for the gas and

water pipes, to have both intimately connected. Finally, I would mention two cases of lightning striking rods closely united with the gas and water pipes. The first happened in Dusseldorf, July 23rd, 1878, on the new Art Academy; the other August 19th, lastyear, at Steglitz. In both cases the lightning rod, the buildings, and the pipes were uninjured."—*Deutschen Bauzeitung.*

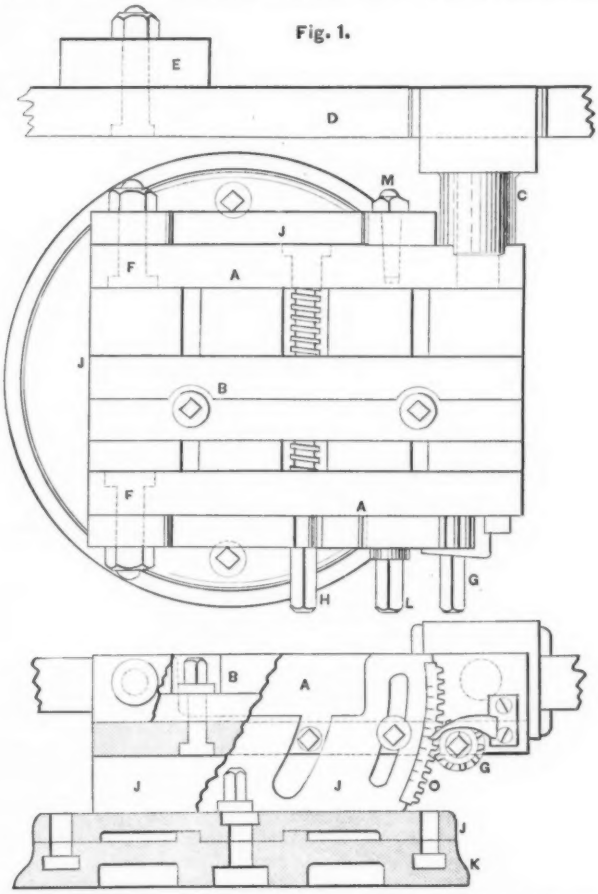
A NEW TOOL FOR MACHINISTS.

By S. W. ROBINSON, Professor of Mechanical Engineering, Ohio State University.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THIS tool passes as a sort of a planer chuck, but in reality it represents the connecting link between the lathe and planer. Heretofore the machinist has been limited in the means for forming circular surfaces. A wide gap has existed till the present in the system of machinist's tools, by reason of which it has been impossible to directly form iron, &c., to circular surfaces, with radii greater than could be done in the largest lathes. I say system, meaning that the

Fig. 1.



cumbersome bracketed attachment to the planer used for planing links, requiring a nest of accessories for special sizes, with nothing complete and general about it, could hardly be considered as belonging to a system. The device, or chuck, now considered, is complete in itself; always ready for dressing a piece of work to segmental circular form of any radius, and completing the range from two or three feet radius to straight, including concave and convex.

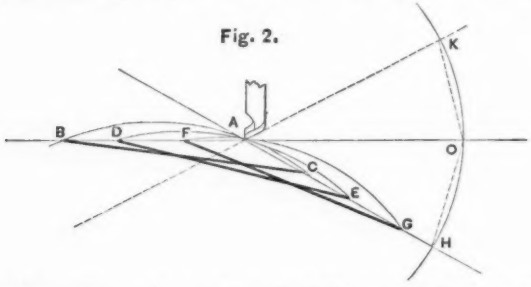
The present intention of the inventor* is to put the invention in the form of a chuck for the planer; but for the sake of the system it may take the form of an entirely new tool, complete in itself from the foundation up. As a planer chuck, in a convenient form, it is well represented in Fig. 1, showing a plan and longitudinal section. It consists of at least three essential parts, viz.: 1st, a bed-piece to set on the planer platen, with two side-pieces or standards; 2d, a vise for holding the work, pivoted by a horizontal axis to the side pieces of the first piece; and 3d, of a guide bar, setable at different inclinations in a vertical plane, and held firmly on the frame of the planer. Along this bar slides a projection from one end of the vise, as the planer is in motion, causing the vise to swing up and down, as a piece of work held in the vise is brought under the action of a tool fixed in the tool-holder of planer, we quite readily see a curve will be cut. Our present object is to investigate this curve on a rigorous mathematical basis. We will state that under one condition it will be theoretically a true circle; and under others, very nearly so, in theory; exactly so, to all intents and purposes, in practice.

* Mr J. H. Greenwood, Columbus, O.

Before taking up the theory, it will be advisable to describe the chuck in one good form, in fact as now made. In Fig. 1, A is the vise for holding the work. It consists essentially of a bottom and side pieces. Between the latter slides a jaw B, forced by the screw H, for securing the work to be dressed. Set screws pass through the jaw, which can be finally set against the work for greater security. The screw H draws instead of pushes, so as to avoid springing the vise bed. At one end of the vise are the pivots F, about which the vise swings. These pivots are fixed in the side pieces J, of the next piece below B, and constitute the horizontal axis about which the vise swings, as stated. The side pieces J are solid on one bed piece, also marked J, all carried so as to swing around horizontally on a base plate K, which latter is secured to the platen by bolts and dowels. The edge between J and K is graduated, so that any angle can be set off. When the vise is set level, and fixed in J, by the taper pin M, we have an index chuck. Hence it is never necessary to remove this chuck to put on a common one. At C is the cross-head socket projecting from one end of the vise. The cross head is gibbed upon D, and swiveled in C. At E is a bracket bolted to the body of the planer below the platen. It serves to fix the guide-bar pivot E. At the other end of D is a slotted arc for making fast that end. This arc is bolted to the uprights of the planer, and by it this end of D can be set to any inclination up or down.

In attaching the chuck to the planer, two points should be carefully observed. 1st. The guide pivot E should be placed exactly at the height of the chuck pivots F. 2d. The same point E should be no farther forward or back than exactly op-

Fig. 2.



posite the point of the average tool, held ready for work in the tool-holder of the planer.

These points observed, we readily see that Fig. 2 is a correct diagrammatic exhibit of those parts of the chuck which constitute the new features. Thus, BAO is the path traversed by the "chuck pivot," while AGH is the guide bar, and A the "guide pivot." Also, A is one tool position. The vise is represented in three successive positions, viz., BC, DE, and FG, BDF being positions of the chuck-pivot, and CEG the corresponding ones of the cross head. This diagram answers to the supposition that the observer stands upon the floor alongside the planer. But suppose the observer to station himself upon the vise of the chuck while in operation. Then the vise appears stationary, while the tool and guide pivot A, the chuck-pivot path BAO, and the guide bar AH, appear to move.

Fig. 3.

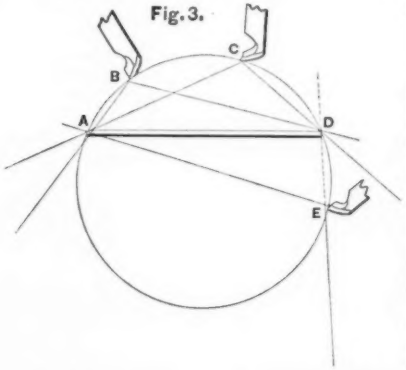
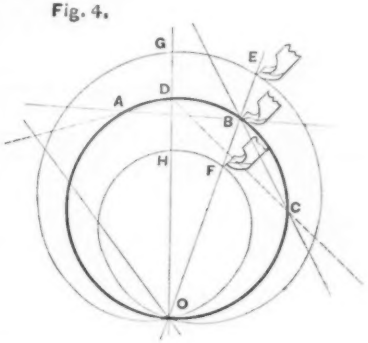


Fig. 3 is at once seen to answer to this supposition, where AD is the stationary vise, and B, C, E, &c., positions of the tool and guide pivot. The chuck-pivot path and guide bar will appear to occupy the positions ABD, ACD, AED, &c., corresponding to the tool position named.

This diagram brings us directly to the geometry of the chuck. From the nature of the case, we know that while the chuck is in operation, planing any given piece of work, the angles ABD, ACD, &c., are all equal. From geometry, we know that the curve passing through A, B, C, D, E, &c., is a circle, because the constant angle ABD, ACD, &c., is measured by half the circular arc AED. Hence, when the tool is at the guide-bar pivot, the chuck "planes" a circle arc exactly in theory. In practice this circle arc sweeps through space while being planed, as Fig. 2 shows, and there is probably doubt as to the circular form of the tool cut line, where the tool is raised or lowered, or forward or back of the guide pivot.

Fig. 4.



By the help of Fig. 4, we gain an insight to the nature of the curves when the tool is displaced. This figure is an extension of Fig. 3. Let ABCO stand for the circle of Fig. 3, cut when the tool is at the guide center, and EG the curve cut when the tool is raised to E. Draw the straight line EBO through E and B. It makes a certain angle with the chuck pivot path AB, and with the guide-bar BC. These lines move to AD and DC when B moves to D. A line GDO will make the same angle with AD as EBO does with AB, because the angles ADO and ABO are measured by half the arc AO. Hence, if DG=BE the tool E will be at G, when B moves to D, because in practice the tool, in making a cut, remains stationary relatively to the guide bar, &c.

From these considerations we find a simple means for constructing the curve EG on a drawing board. We only have to draw a circle ABO, Fig. 4; then through O draw any desired number of straight lines, distributed about, and then, with a constant span in the dividers, lay off BE, DG, &c., on all the lines. Then trace the curve through the points EG, &c., thus found. The curve runs into the point O from both sides, and is sometimes classified as a

conchoid with a circular base; sometimes as the limagon of Pascal. (See VAN NOSTRAND'S SCIENCE SERIES No. 47, by J. D. De Roos, reprinted from this MAGAZINE.) If the tool be lowered to F, we have the same curve, but inside the base circle, and constructed by laying off BF on all the lines, when BF=BE the two curves are one and the same, continuous through O.

This curve is evidently one of varying curvature, and hence not circular at any part. It remains to be shown whether the curve will deviate from a circle appreciably within the limits reached in practical use of the chuck. This can only be determined by aid of qualitative results, computed from rigorously correct formulas. Drawings cannot be made accurate enough for the present purpose.

Let R=radius of the circle ACO, Fig. 4.
r=radius-vector of the conchoid pole of co-ordinates at O.
ρ=radius of curvature of the conchoid.
θ=angle to r.
α=angle to ρ.
a=elevation of tool, minus for lowered.
x=deviation of curve from circle.
Also $r=r_0$ & $\rho=\rho_0$ for θ & $a=o$.

Then the polar equation of the curve, pole at O, and θ reckoned from at diameter through O, is

$$r=2R\cos\theta+a \quad . \quad . \quad . \quad (1)$$

which is evident from the fact that $2R\cos\theta$ is that part of r, between O and the circle, as OD, and a is the part DG, when the curve is inside the circle, a is minus, and

$$r'=2R\cos\theta-a \quad . \quad . \quad . \quad (2)$$

To find the radius of curvature for any point G, we may apply the differential formula of the calculus. Substituting into it the differential coefficients obtained from (1) we have

$$\rho=\frac{(r^2+4R^2\sin^2\theta)^{\frac{3}{2}}}{r^2+8R^2\sin^2\theta+2Rr\cos\theta}$$

$$=r\frac{\left(1+\frac{4R^2}{r^2}\sin^2\theta\right)^{\frac{3}{2}}}{1+\frac{8R^2}{r^2}\sin^2\theta+\frac{2R}{r}\cos\theta} \quad . \quad . \quad . \quad (3)$$

for which r is given by (1).

If r' from (2) is used, the radius of curvature obtained is for the inside curve.

When $\theta=0$, we obtain

$$\rho_0=\frac{r_0^2}{r_0+2R}=\frac{(2R+a)^2}{4R+a}$$

$$=R+\tfrac{3}{4}a+\frac{a^2}{4(4R+a)} \quad . \quad . \quad . \quad (4)$$

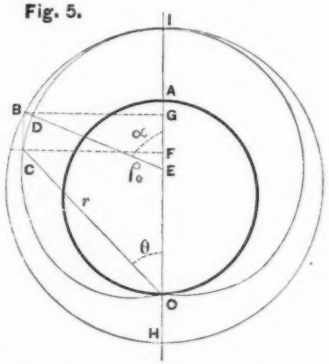
$$\rho_0-R=\tfrac{3}{4}a+\frac{a^2}{16R}=\tfrac{3}{4}a, \text{ nearly} \quad . \quad . \quad . \quad (5)$$

The 3d expression of (4) comes from algebraic division after developing the numerator of the 2d. Eq. (5) comes from the last of (4) by dropping a from the denominator and transposing R. This eq. (5) is important, because it shows the change in the radius of the work cut when the tool is raised or lowered, with respect to the guide pivot.

Solving (4) for r_0, observing that $2R=r_0-a$, we obtain

$$r_0=\rho_0\left(1+\sqrt{1+\frac{a}{\rho_0}}\right) \quad . \quad . \quad . \quad (6)$$

Fig. 5.



In Fig 5, let GO represent the base circle, ICO the conchoid, and IBH the circle of radius ρ_0, which osculates with the conchoid at I. Then BD is the perpendicular, or normal departure of the conchoid from the osculatory circle, and shows how much the curve, planed in the chuck, departs at B, from the circle it begins to cut in starting at I, when the tool is raised to the height AI. The magnitude of this is of the utmost importance, for upon it the utility of the invention in a great measure depends; that is, if it is found to be always too insignificant to perceive in practice, the

non-circular character of the curve cut can be ignored, and the chuck used as though theoretically perfect. The value of $BD=x=BC\cos a$, and $BC=GF=GE+EO-FO=\rho_0\cos a+r_0-\rho_0-r\cos\theta$. Hence

$$x=(\rho_0\cos a+r_0-\rho_0-r\cos\theta)\cos a$$
$$=\rho_0\left\{\cos a+\left(\frac{r_0}{\rho_0}-1\right)-\frac{r}{\rho_0}\cos\theta\right\}\cos a \quad . \quad . \quad . \quad . \quad (7)$$

The relation of θ and a is

$$\rho_0\sin a=r\sin\theta.$$

We readily see from Fig. 5 that when the tool is raised up along the continuation of the diametrical line OA to I; the work should be so disposed in the chuck as to be dressed to include equal portions of the curve like IB on each side of I. This very nearly follows in practice as a matter of course, but not exactly since the tool will move in a line EBF, perpendicular to the chuck-pivot path AB Fig. 4. But as the angle ABC is in practice 180° within 15° or less, there is but little chance for error here. Also it is plain that when AI, Fig. 5, is large, x is greater. Again if the radius EI is small for a given length of work, x is greater.

We will take an example, which thus represents an extreme case, in which the radius is R=30 inches, the length of work 24 inches, and the elevation, or depression of tool, a=4 inches. The necessary computations give for

TOOL ELEVATED.

$r_0=2R+a=64''$
$r=62''.8978.$
$\theta=11°$
$\rho_0=33''.0323$
$\rho=32''.9806$
$\rho_0-\rho=+''.0517$
$x=\ \ ''.000614$

TOOL DEPRESSED.

$r_0'=2R-a=56''$
$r'=54''.4622$
$\theta'=13°$
$\rho_0'=27''.0345$
$\rho'=27''.1168$
$\rho_0'-\rho'=-''.0823$
$x'=-''.00219$

The values of r, r', ρ, and ρ' are for the ends of the piece 2 ft. long, supposed, in the example, to be planed off. The intercepts x and x' are also at the ends of the work. In practice we probably never would have occasion to work to a shorter radius, or to a greater length of piece for that radius, and never with a greater elevation of tool; in short, never would give cause for greater theoretical departures from the strictly circular form, and yet we find it to be less than a thousandth of an inch for the outside curve, and only about two thousandths for the inside one. These are undiscoverable by means in the hands of machinists, applied to pieces of the size considered, and hence of no practical consequence. Considering again that the departure is from a circle fitting the middle of the work, and not from that one going through the three points consisting of the midddle and end points; we find that the departure computed appears in its exaggerated form. When a three-point templet is used in connection with the chuck for fitting up the work, the triple contact comparison circle will be the one realized. Then the departures will be only about a fourth as large as the computed ones, as can be shown from an approximate law of curves not necessary to discuss here. They can, in fact, be seen to be much smaller.

When we thus find that the theoretical departures of the work produced by the chuck, from the desired circular form, can never exceed two thousandths of an inch at the worst, and generally will not exceed about half a thousandth, of course there need be no hesitation, on theoretical grounds, about adopting the chuck. And, finally, when we consider that the practical errors due to elastic yielding of materials, imperfections in sight, measurements, &c., will swallow up all the theoretical ones without knowing the difference; that is, when the theoretical errors of the chuck utterly vanish within practical ones foreign to it, but incident to its use, we may safely assume that for all practical intents and purposes this chuck is a theoretically perfect tool, and may be offered as such.

In using the chuck for fitting work, two methods are available for securing a given radius to the circle planed. 1st a three-point templet, or, if preferred, a circular templet may be employed. And, 2nd, a table of setting values for the

guide bar. These may be used separately or conjointly; probably the latter will always be found preferable.

The templet method supposes a templet of some form. It may be a circular segment, cut from sheet metal. Where much work is repeated to the same radius, such a one will be more durable than that of three points, though the latter can be produced most readily. An adjustable templet or gauge will be found convenient, in which one of the three points, or legs, can be set by a scale and vernier, according to a table prepared for it.

The table method of setting the chuck requires a table of values of radii of work, and of the angular elevation or depression of the guide bar. In Fig. 2, the position AH of the guide bar may be determined by the chord OH, called the "setting," the same being set off by a steel rule. Similarly OK is the chord for the opposite setting.

To compute values of these chords, take the setting OH, or OK equal y. Take $AO=AH=d$. Also take the angle $OAH=\varphi$; and the length of the vise, from pivot to cross head, $=l=BC$ or FG, Fig. 2. Then

$$Ok \text{ or } OH=y=2d\sin\tfrac{1}{2}\varphi. \quad . \quad . \quad . \quad (8)$$

Also in Fig. 3, supposing E to be diametrically opposite A, observing that $AED=\varphi$, we would have

$$AE\sin\varphi=AD=2R\sin\varphi=l \quad . \quad . \quad . \quad (9)$$

From these equations, y can be computed for assumed values of d and l; φ being regarded as an auxiliary quantity. By eliminating φ, we obtain

$$\frac{R}{l}\left(\frac{4d^2}{y^2}-1\right)^{\frac{1}{2}}=\frac{d^2}{y^2} \quad . \quad . \quad . \quad (10)$$

which shows that R varies directly as l, and y directly as d. This must be observed in changing a table for any one chuck to fit another. In addition to these "settings," the table should contain "setting corrections" to use in compensating the radius of the work for elevation or depression of tool. That is to say, when the chuck is set for a given radius of 60 inches, for instance; then if the tool should be raised 2 inches, by which a change of $1\frac{1}{2}$ inches in the radius is occasioned (see eq. (5)), we should have a value of the change of setting required to restore the 60 inch radius. This is the "setting correction."

The relation sought in this, is that between differences of the radius and differences of the settings, or between $d\rho_0$ and dy. This relation can be found from eqs. (5), (8), and (9), observing the conditions that when the tool is fixed at a certain point in height, we change the setting to effect a change in ρ_0. In doing this we vary φ, and R. Hence the 1st of (5) gives

$$\frac{d\rho_0}{dy}=\left(1-\frac{a^2}{16R^2}\right)\frac{dR}{dy} \quad . \quad . \quad . \quad (11)$$

By aid of (8), and $\sin\varphi=2\sin\tfrac{1}{2}\varphi\cos\tfrac{1}{2}\varphi$, (9) may be transformed to $2Ry\cos\tfrac{1}{2}\varphi=ld$, whence

$$\frac{dR}{dy}=\frac{R\sin\frac{1}{2}\varphi}{2\cos\frac{1}{2}\varphi}\frac{d\varphi}{dy}-\frac{R}{y} \quad . \quad . \quad . \quad (12)$$

And (8) gives

$$\frac{d\varphi}{dy}=\frac{1}{d\cos\frac{1}{2}\varphi} \quad . \quad . \quad . \quad . \quad (13)$$

Combining eqs. (11), (12), (13), & (8), with (9) transformed, we obtain

$$\frac{d\rho_0}{dy}=-\frac{R}{y}\left(1-\frac{a^2}{16R^2}\right)\left(1-\frac{R^2y^4}{l^2d^4}\right) \quad . \quad . \quad (14)$$

By dropping the last term in each of the bracketed expressions, we introduce an error which only reaches a hundredth of an inch for one or two of the greatest corrections, in others it being less. Hence the simple relation

$$\frac{d\rho_0}{dy}=-\frac{R}{y} \text{ nearly} \quad . \quad . \quad . \quad (15)$$

These formulas give but little idea of the table, and much depends upon them in the line of practical convenience. A specimen of the tables is given to enable the reader to judge of their applicability.

TABLE FOR SETTING THE CHUCK.

Radius of curve planed. Tool point at "guide-pivot."	"Setting" of guide-bar, 2 ft. from "guide-pivot."	"Setting correction" for tool, 1 in. up or down, to plane a given arc.
Inches.	Inches.	Inches.
195.03	1	.004
156.02	1.25	.006
130.07	1.5	.009
97.58	2	.015
78.11	2.5	.024
65.13	3	.034
55.86	3.5	.047
48.92	4	.062
43.53	4.5	.077
39.21	5	.095
35 69	5.5	.115
32.77	6	.135

TABLE OF INSTRUCTIONS.

Curvature planed.	Tool raised or lowered.	Radius of planing.	Setting, up or down.	Correction of setting.
Convex.	Raised.	Increased	D'nward	Add.
"	Lowered	Decreased	"	Subtract
Concave	Raised.	Decreased	Upward	Subtract
"	Lowered	Increased	"	Add.

NOTE.—"Guide pivot" is the pivot of guide bar, and the chuck pivot should be at the same height.

Each inch the tool is raised or lowered makes $\frac{3}{4}$ inch change in the radius planed, except the setting is corrected as in last column of table.

What is here termed the "setting" is the length of the chord OH or OK. Fig. 2. When AO = AH = AK = 24 inches, and the length of the vise from chuck pivot to axis of cross head is 16$\frac{1}{4}$ inches.

The "setting correction" is to be applied to the "setting," for the purpose of restoring the given radius planed, after the tool has been raised or lowered.

When the tool is back of the guide pivot, that end of the work, which is in the opposite direction, has slightly the sharpest curvature, and *vice versa*.

As regards the seeming multiplicity of the means for setting the chuck to its work, and the possible objection to it which may be imagined on this ground, it is but fair to mention the fact that the table may be regarded and treated as a convenience instead of necessity. Setting the table aside, and adopting the three-legged templet, we are on an equal footing with the lathe and its calipers for working to given dimensions. In the lathe we think nothing of setting the calipers by a scale, rounding the piece of work and trying on the calipers. If not a fit, we cut and try again—and again—till correct. Exactly so with the chuck and its templet. But the chuck is more complete than the time-honored lathe, in that it has a means of coming directly to the mark, while the lathe has not.

The great indebtedness of iron manufacturers to Mr. Greenwood, for this valuble invention, can only be duly appreciated by observing the important gap which it fills in the system of machine tools, and the readiness with which surfaces may now be produced, which could not heretofore be employed to any extent, from the impossibility of producing them plentifully.

HELIOGRAPHY AND SIGNALING.

By MAJOR A. S. WYNNE.

From the "Journal of the Royal United Service Institution."

IT is now nearly five years since a lecture on the heliograph or sun-telegraph was delivered by Mr. Samuel Goode, who claimed for Mr. H. C. Mance, of the Government Persian Gulf Telegraph Department, the invention of this valuable instrument for signaling purposes. It was then explained that as early as the year 1869, Mr. Mance brought his heliograph to the notice of the Government of India. It was very favorably received, and subsequent reports testified to the success of experiments which had been tried to ranges of 50 miles without telescopes, one memorandum going so far as to state that with a 6 or 8-inch mirror, signals could be seen with the naked eye at a distance of 100 miles.

Since then the heliograph has fully realized the expectations of its supporters. The Government of India sanctioned its adoption in 1875, and each succeeding year its efficiency has been more and more generally recognized. It was used for the first time on active service, in India during the Jowaki-Affridi Expedition of 1877–78, and in the campaigns of the last two years in Afghanistan and Zululand it has has been put to every possible test, with such satisfactory results that it must soon become an established addition to the Signaling Equipment of all armies.

It is not my purpose to advance the many instances in which sun-flashing has been employed advantageously elsewhere

than on the northwestern frontier of India. Most of us have read with what good effect it was eventually used at Ekowe and in the subsequent operations against Cetewayo and Seccocoeni; of its having been brought into play by the Spaniards across the Straits of Gibraltar; and by our own people in Australia and the West Indian Islands. We know that it forms part of the signaling equipment of the United States Forces, and as I am informed of other armies, all of whom will have points of interest to record.

My experience of the heliograph has been mainly acquired in a practical way on service. I have nothing to add to the theoretical knowledge of sun telegraphy; but as I had the honor and good fortune to be placed in superintendence of the signaling operations with the Peshawur Column of the Jowaki Expedition and of the Kuram Column during the first phase of the Afghan Campaign, I shall endeavor to explain as far as possible the results obtained and the inferences to be drawn from the working of the heliograph during those campaigns; and if any hint or suggestion I can give should prove of assistance to such of my brother officers as may at any time be similarly placed, I shall not regret that my diffidence in appearing here has been overcome.

Origin of the Heliograph.—Reviewing rapidly the origin of the heliograph, the system of utilizing sunlight as a means of communication seems to have been known to the ancient Greeks and Romans. In the earlier part of this century a sun-flashing instrument called the heliostat was used in survey operations; and by its means triangles with sides exceeding 100 miles each were laid down in the Survey of the British Isles. The heliotrope, an improvement on the heliostat, has long been and is still very generally used; though somewhat cumbersome, its construction is simple, and it is provided with the means of horizontal and vertical adjustments. Then came the heliograph, which, like most inventions when once introduced and established, seems so simple, that the wonder is the other instruments did not sooner suggest the idea of utilizing the sun as a signaling agent, by converting rays of light into active speaking signs, and adapting the flashes to a code.

While there will be something to learn from every new experience of the use of sun-flashing, it may be well to guard against many doubtful reports that are current of its application. Thus, while it is, no doubt, true that some primitive method of sun-flashing has long been employed by the North American Indians for war purposes, I have seen it stated that when some years ago, in the plains west of the Missouri River, 3,000 warriors of the Dakota tribe encountered an invading column of the United States Army, they not only adopted regular formations for attack and defence, but were maneuvered by means of a looking-glass which their chief held in his hand. The strong ray of reflected sunlight it is said was thrown on the ground, and moved in whichever direction the chief wished his force to take, they following the flash as it moved along the ground. At first sight this seems plausible enough, but to any one conversant with sun-signaling, the impracticability of the alleged method is at once apparent, for the flash from even a very large mirror, if projected on to the ground, becomes invisible at 100 or 200 yards distance, both to the signaler and those signaled to. Again, it is said that the Russians made use of sun-flashing for signaling purposes during the siege of Sebastopol; the following extract from a letter of the *Times* Correspondent having appeared on 11th July, 1855:

"A long train of provisions came into Sebastopol to-day, and the Mirror Telegraph, which works by flashes from a mound over the Belbeck, was exceedingly busy all the forenoon;" it is singular, however, if such were the case, that they should have so forgotten the art as not to have employed it during the late war with the Turks, when on many occasions it would have been of such value. For instance, in Asia Minor a pre-arranged joint attack was to have been made on the Turkish position, a few miles east of Erzeroom, by two columns marching along converging routes; one column was, however, delayed, and a separate instead of a combined attack resulted in the defeat of the Russian forces in detail, who were driven thence back to Kars. Had intercommunication been maintained by sun-flashing (and I have no doubt it was feasible) the march might have

been so timed as to insure a simultaneous assault. If the Russians had possessed a sun-flashing instrument, one might have expected to see it employed as a means of communication across the Danube and round Plevna, but so far as I can gather, heliographic signaling was not resorted to throughout the campaign. It is not improbable—but I throw it out merely as a suggestion—that the flashes came from some reflecting surface accidentally placed in line with the English camp. I have often seen effects not easily distinguishable at first from heliographic signals. For instance, during the three days General Roberts' force was encamped below the Afghan position at the head of the Kuram Valley, attention was attracted each morning at sunrise by flashes from the enemy's camp, and it was thought at first that they had a heliograph; but a careful scrutiny through a glass showed the light to be from the muzzle of a polished brass field gun. We may be sure that if the Russians had employed a signaling mirror they would not have exposed the signals to our observation, also that the fact would have been prominently mentioned in their official reports of the siege.

The introduction of the heliograph cannot fail to have a stimulating effect on army signaling generally. Various methods of conveying intelligence to a distance by signals have been in vogue during the last few years in both the army and navy. So long ago as 1851, an "occulting telegraph" was invented by the late Charles Babbage, in which it is said the Duke of Wellington took much interest, and when the report came home during the Crimean war that the Russians were using a mirror telegraph which worked by flashes, the inventor addressed a letter to the *Times*, and suggested the idea of adapting sunlight to his system. Nothing seems, however, to have come of it, and until quite lately the army has been contented, or rather discontented, with such apparatus as flags, semaphores, shutters, lamps, &c., &c. For, notwithstanding all the methods of communication which have from time to time been adopted (and the system and apparatus of Captain Colomb and Colonel Bolton are very admirable), and however useful they may have proved in their different spheres, it is undoubtedly a fact that army signaling has languished, chiefly owing to the limited powers of the apparatus employed. Even the best of all signaling means, the field telegraph, is not without its defects, some of which I shall have occasion to allude to later on. Like everything else, sun signaling has serious shortcomings, still the heliograph has proved both in India and Africa a valuable addition to Army Signaling Equipment. Amongst the many advantages that may be fairly claimed for it are its great range, portability, the ease with which it can be established and communication maintained, and the rapidity of its working. If the ranges at which the operations during recent campaigns were conducted seem somewhat short, it must be remembered that the stations were established to suit the positions of the troops, and that experiments to test the limit of the range were not attempted. For instance, we read of twenty-four heliograph stations having been employed between Cabul and Jumrood, but it must not be inferred from this that when through communication is required, so many points are necessary, for the whole distance of 180 miles from Cabul to Peshawur can, without difficulty, be accomplished through four intermediate stations, signaling between Cabul and the heights above Jellalabad, distant 75 miles, having been successfully carried on through a single station at Luttabund. It may be stated that under favorable conditions of sun and atmosphere, any two points visible to each other can be brought into communication.

Description of the Heliograph.—Several patterns and sizes of heliographs exist, in some of which there are departures from the original Mance instrument. The heliographs here, one of which is from Roorkee, have been kindly lent by Mr. Goode. I am sorry I have none of those made more recently in India, for the regiments out there are exclusively equipped with instruments made in the Government workshops there, on the Mance principle. The Superintendent of the Canal Foundry has taken especial interest in their manufacture and been ready at all times to carry out suggestions for improvements

in constructive details. However, without entering into slight differences of construction, I will describe the instrument now before you. It consists of a signaling mirror, reflector, sighting vane, and two tripod stands. The signaling mirror is so connected to the framework of the instrument that its inclination can be regulated horizontally or vertically. A tangent screw engaging the base plate enables the frame to be rotated, and a telescopic rod clamped to the signaling key lever, and working by screw through a nut at the top of the mirror, effects the vertical adjustment. There is a small circular hole in the frame of the mirror, and a corresponding unsilvered spot in the mirror itself, to enable an alignment with the distant station being taken when looking through from the back of the instrument.

The reflector is used when the sun is behind the operator, and should replace the sighting vane whenever the angle made by the sun, the heliograph, and the distant station exceeds 120°. The reflector has a sighting vane attached to its surface.

The sighting rod is so jointed that it can be readily moved into any position, it fits on to one of the stands, and has a silvered sighting plate, with a black spot in the center called the sighting spot.

One tripod stand supports the signaling mirror and the other the reflector or sighting vane as required.

Sighting with Sun in front of Signaler.—The usual method of directing the flash to the required point has been to look through the mirror from the back and move the sighting plate until the sighting point is exactly in line. But a simpler and very accurate way is to "stand in front of the mirror and looking into it, bring the eye into such a position that the spot in the center of the mirror hides the reflection of the distant station. Then move the sighting rod until the reflection of the sighting spot comes into an exact line with the other two objects." The flash is then thrown on to the sighting vane and is rightly aligned when the dark shadow spot in its center coincides with the spot on the vane. The shadow spot is occasioned by the center of the mirror being unsilvered.

When the heliograph is adjusted, there is no chance of the alignment being disturbed, for however much the inclination of the mirror may be altered, its center, being the axis on which it turns, remains stationary.

Sighting with the Sun behind the Signaler.—When it is necessary to use both mirrors, place the signaling mirror facing the sun and the reflector inclining towards the distant station, stand in front of the heliograph and looking into the mirror so that the whole of the reflector can be seen reflected, move the latter horizontally or vertically, until the distant station, the spot on the reflector, and the unsilvered spot on the signaling mirror are in the same line.

Signaling.—The Morse code is so universally known it may be hardly necessary to remark that it consists of an arrangement of dashes and dots, or longs and shorts, to represent the letters of the alphabet, one of the former being equivalent in duration to three of the latter. The short flash from the heliograph is almost instantaneous, while the long is visible for an appreciable time. By an arrangement of these signs no letter involves more than four signs, whether dots or dashes.

According to the Army Signaling Regulations, no abbreviations are permitted; but I think this is a mistake, and cannot see why those authorized in telegraphy should not be adopted, or at all events those most commonly used.

The "General Answer," which consists of a succession of longs and shorts, kept up until the next word or group is commenced, should be abolished for the heliograph. The instruments receive more rough usage from it than from all the messages despatched. One flash kept up till the commencement of the next word is the best answer, signifying that the word or group is understood, and two short flashes for "not understood" signifying that the word is to be repeated. In the Regulations there is no sign laid down for "not understood," they provide that the word should be repeated if after a reasonable time elapses no answer is sent. And though theoretically this interval is limited to a pause equal to two longs, yet in practice a much greater lapse takes place, the sender hoping that the receiving station

may be induced to take the word on reading the pretext of the message. This causes a serious loss of time which would be obviated by a "not understood" signal. It is these unnecessarily long intervals between words which take up so much valuable time.

When the signaling key lever is depressed, it alters the inclination of the mirror according to the play allowed by an adjusting screw, and if the flash was before truly aligned on the distant observer, it would then be thrown over his head, and become invisible to him, but the pressure being removed the flash would return to its original position and reappear.

Heliographic signaling can be carried on by flashes or the obscuration of a fixed light. In the former case, *when the key is depressed* the center of the flash is directed on to the sighting vane and is then seen by the distant station; when the pressure on the key is released the flash falls and disappears from view. In the latter case the center of the flash is thrown on to the sighting spot and appears as a fixed light to the distant station until the key is depressed, when the flash is thrown upwards. In both instances the method of signaling is the same; long and short flashes, or long and short obscurations resulting from the periods of pressure applied to the signaling key, and in this way the letters of the alphabet according to the Morse code and other useful combinations can be signaled.

Flashing is the system in vogue in the army in India, and is more generally adopted than that of obscuration.

In signaling the left hand is kept on the tangent screw and the right on the signaling key. The necessary adjustments to suit the (apparent) motion of the sun can thus be simultaneously made, while in the act of signaling, without any interruption or delay.

Advantages and Capabilities of the Heliograph.—It has been generally admitted throughout the Afghan campaign, that without heliographs no satisfactory communication could have been maintained. Until the operations developed and arrangements were made with the tribes, no dependence could be placed on the lines of field telegraph, the working of which was constantly rendered inoperative by malicious cutting. Taking the Khyber line for example: up to October, 1879, on a total distance of 108 miles of line, it was cut 98 times and 60 miles of working wire was carried away and never recovered. Considerably more damage has been since committed, and the recent operations at Cabul prove that when most needed the telegraph is almost sure to be cut. In December last, during the investment of Sherpur, the greater part of the line between Cabul and Gundamuck was entirely destroyed. But here the heliograph did good service, enabling the Sherpur garrison to hold communication with the solitary outpost at Luttabund, the connecting link with their supports, along the Khyber route, by which means General Roberts was able to assure the army in India, and the Government at home, of his security, and to issue important orders regarding reinforcements.

The service the heliograph has rendered in other ways during the campaign has been scarcely of less value, and the long lines of communication which by its use have been kept open have not only assisted the operations in the field, but spared cavalry and infantry much harassing duty in conveying messages from post to post.

Flags were quite useless as a rule to work over the distances which separated brigades and detachments; henceforth they will probably be confined to sunless days, for when the distance exceeds 4 or 5 miles a flag of such size must be used that working it for any length of time entails much physical labor and is tediously slow. Small flags for shorter distances may, in many cases, be of great service, but generally speaking as the distance diminishes it will be found quite as convenient, if not as expeditious, to despatch messages by mounted men or even foot messengers if the heliograph cannot be worked.

Amongst the many merits of the heliograph, the ease and certainty of attracting attention must not be overlooked. Every inch of country visible can be gradually searched by its means, and the positions of parties unknown before ascertained. If the tangent screw is pressed outwards, the mirror will turn freely right or left, and by loosening the screw which clamps the key-rod in

its socket, the inclination of the mirror can be raised or lowered at pleasure.

The capture of the Peiwar Kotal on the 2nd December, 1878, was effected by two columns, one of which attacked in front, the other in flank. The configuration of the country did not admit of direct heliographic communication between them, but it was practicable by the establishment of an intermediate station. The detached signaling party, however, failed to reach the pre-arranged point, but by flashing all over the hillside in the way I have indicated, their actual position was discovered, and interchange of messages effected.

During a surveying expedition made in January, 1879, from Khost into the Waziri Hills under Captain (now Major) Woodthorpe, R.E., I accompanied the party, and from one of the first hills where the surveying plane table was set up, Banu, a station 35 miles distant, and within the frontier of India, could just be seen lying at the foot of the hills on the banks of the Kuram River, and apparently not far from the Indus. A heliograph was directed on Banu, and although no previous intimation had been given, and there was only one officer present at the station who possessed a heliograph, communication was soon opened; signaling had all along been maintained with the Head-Quarters at Khost, and messages were now passed between General Roberts and the officer commanding the frontier. Banu being also in connection with the telegraph system of India, a message from the General was dispatched to the Viceroy at Calcutta. It was afterwards found that a native sentry had noticed the flash from the hills and given intimation. From the same point, communication with Hasar Pir (distant 19 miles) was established, the attention of the signalers having been easily attracted.

From the Kandahar Field Force, it is reported that on the 12th December, 1878, a camp being discovered lying under the Kojak Range, distant 20 miles, a heliograph was laid on it, and a reply soon received. After marching 8 miles further on the same day, communication was opened with a camp 25 miles off, which turned out to be the headquarters of General Biddulph's division.

Again, on the 29th May, Captain Straton, Superintendent of Army Signaling with the Kuram Field Force, ascended the Sufed Koh—a range of mountains 15,000 feet above sea level, and separating the Kuram and Cabul valleys. Intimation had been sent to Jellalabad, warning the signalers to be on the alert, but when Captain Straton reached the top of the Agam Pass, he found Jellalabad obscured in a dust storm which continued throughout the day; however, he proceeded to the Karaini Peak, close by, and carefully scanning the Cabul Valley through a telescope, discovered a camp which proved to be Gundamuck, distant about 30 miles. With Mance's 3-inch heliograph he attracted attention, and in fifteen minutes Generals Roberts and Browne, Commanding the Peshawur and Kuram Columns, were in communication.

More recently, with the Zaimusht Expedition under General Tytler, the force was divided into three columns which separated at Mundatoo under Colonels Gordon, Rogers, and Low. The "Pioneer" correspondent accompanying the force writes: "The utility of having this knowledge was well illustrated as we returned from Gondaleh. . . . We caught sight of distant high peaks overhanging the camp at Mundatoo. Over these hills Colonels Gordon and Rogers had taken their troops the day before. Suddenly from about half-way down one of them flash, flash, flash come on to us. . . . Colonel Low called his signalers up, the message was from Colonel Gordon to General Tytler informing him that both would reach the head-quarter camp that night. Thus General Tytler knew the position and whereabouts of all the troops out."

But perhaps one of the most prominent services rendered as yet by the heliograph was during Captain Straton's visit to Jellalabad in January last. On the 12th of that month, when at the signal station of Alibogham, he found out that the Momunds had crossed the Cabul River; this intelligence he at once flashed off to Jellalabad, and that night a brigade started to intercept the enemy. During the following day, communication was successfully maintained between General Bright's head-quarters at Jellalabad, the brigade set out, and a detachment of it, crowning the heights.

At 1.15 P.M. (13th), Captain Straton saw about 1,500 men trying to cross the river, at such a point that, if they had succeeded, the brigade would have been cut of from Jellalabad, and the detachment severed from its main body. But intimation was at once signaled to all concerned, and by 3 P.M. a couple of guns sent out from Jellalabad were shelling the enemy with such good effect that they beat a hasty retreat.

I might quote many other instances of the kind, but those already given suffice to prove that with the heliograph no pre-arrangement as to time or place is, even up to such distances as 35 miles, absolutely necessary.

Signaling by moonlight with the heliograph has been practiced during the last two years on service, and it is hoped that the results will soon be published. I have tried it on two different occasions; first in the Jowaki campaign between General Ross's standing camp and the Sargasha Ridge, and subsequently between Jutogh and Subathu, distant 12 miles. The signals were intelligible in each instance, but the heliographs and telescopes were set up by day and remained in position till the moon rose, otherwise it is doubtful whether the alignment could have been hit off, unless signal fires had been used. At the time communication was established between the Cabul and Kuram Valleys, advantage was taken of a full moon, and a heliograph set on Kuram from the Agam Pass. The light was seen with the naked eye 12 miles off. Selinagraphing might often be very profitably employed; clear nights are the rule in India, and signaling by the reflection of a planet has been carried out for short distances.

Heliographs can also be used with artificial lights; during the investment of Sherpur, they were worked at night with the reflected light from lamps between the different faces of the works, and to the picquets on the adjacent heights where no telegraph existed. It may at first sight appear strange that a reflected light should be used instead of the direct light itself, but the ease and silence with which the movements of a mirror are made render the employment of the heliograph preferable to the extreme difficulty of preserving the alignment of a lamp, and the noise of its screen or shutter. The light being stationary, signaling proceeds uninterruptedly without any fresh adjustment being necessary. But with the regulation lamp issued to regiments in India, if the stations are any distance apart, it is very hard to keep the lamp held constantly in the exact direction which gives the receiving station most light, and if there is much work to be done, a man's arm gets stiff from holding it so long in the same position.

It has often been advanced as an argument against the adoption of the heliograph, that it is useless without the sun. The argument is unanswerable, but even the telegraph line is not proof against weather. With the Kuram Column field telegraphs were laid on posts without insulators; dust soon filled the notches cut in the posts, and when rain fell the electric current was greatly weakened or entirely lost. The ground line laid by the Field Train, from exposure to weather, suffered in a like manner, for the guttapercha covering being liable to crack, often on a rainy day the sounders in a telegraph office were as idle as the heliographs. But in a climate like India, it is surprising how few sunless days there are. Probably the proportion in a campaigning season would only be one in eight.

Clouds are of course a serious hindrance, and usually an effectual barrier to heliography, but to limited distances the flash from a mirror is capable of penetrating any ordinary haze, smoke, translucent clouds, or dust. In the Jowaki-Affridi campaign, the signal party at Peshawur were posted on the church tower; sometimes, owing to dust, haze, or smoke, the church became obscured to view, even through a telescope, and yet the signaling was uninterupted. On the 19th January, 1878, the Peshawur signalers were called up from the Tor-Sapar heights, distance 24½ miles, and through communication was then for the first time opened between the Peshawur and Kohat Valleys; yet on this occasion there was such a haze over Peshawur, that the outline of the church was hardly visible through telescopes.

The earliest reports speak to the penetrating power of the flash from heliographs tried between Shaikh-Bodeen

and Dehra Ismail Khan, distance 38 miles, although the weather was so hazy that the stations were barely visible.

Again, Lieutenant Savage, R. E., Superintendent Field Telegraphs with the Kandahar force, reports that on the 4th January, 1879, "Captain Bishop with General Palliser's advanced cavalry flashed us up at 11 A.M. from about 14 miles ahead, and a message from General Stewart was taken, which was sent on to him. Signaling party rode on several miles, and on receipt of answer, opened communication again and sent it; dust flying so thick that the hill on which the distant party was stationed was nearly invisible, but their flash was like a bright star through the dust."

Under such circumstances as these, no other visual signaling but that of sun flashing would have availed.

Circumstances may often arise when sun flashing would be very desirable, but no proper instruments are available. It may be as well, therefore, to mention that an impromptu apparatus, perfectly effective for temporary purposes, can be devised out of an ordinary shaving-glass in a few minutes. If two sighting points are aligned on the distant station, the glass can be directed truly and satisfactory signaling carried on by exposing and obscuring the flashes with a book or anything else at hand.

Selection of Signal Stations.—The selection of the best positions on which to establish signal stations in a strange country, during active operations in the field, is perhaps more difficult than would at first appear, the difficulty increasing with the distances to which the lines of communication extend. When stations are far apart and the configuration of the country monotonous, the ready appreciation of the best points of observation requires an eye for country and aptitude for locality which cannot be expected from all signalers. An officer should always be entrusted with this important duty; also when there is a press of work at an intermediate station, the presence of an officer is essential to ensure the regular and rapid receipt and despatch of messages, for it often happens in such contingencies that signalers get disheartened when messages accumulate, and irregularities and delays are the consequence.

Sometimes it may be advisable to vary the stations, although still keeping up communication between the same signaling parties, for not infrequently the signal station is unavoidably some distance from camp, and more or less isolated and exposed. The fact of an enemy knowing that at a particular time and place he can rely upon finding a small body of men detached gives an opportunity for, and proves an incentive to, attack which might not be attempted under slightly altered circumstances.

If the country is hilly, and any difficulty is experienced in establishing communication for the first time between parties whose position is uncertain, delay might be prevented by the assistance of signal fires, heaping on damp straw or green brushwood in the daytime, so that a column of smoke would ascend which could be discerned for miles, and clearly indicate the whereabouts of each. As before stated, there is little or no trouble in sweeping the flash from a mirror over all the country within view, but in the case, say, of both parties being on low ground with hills between them, the foregoing plan might be advantageously employed.

Some delay took place in establishing the stations at Hazar Pir and the Peiwar Kotal, because the signal party at the former did not ascend high enough. They distinguished the outline of the long spur extending from the Sufed Koh over which the road runs, and thought they saw the Peiwar Kotal Pass, but the block of hills about the Darwaza-Gai interfered and obstructed the flashes from both parties until a higher line clear of them was established; the distance between the two was 35 miles.

Training of Signalers.—Too much care cannot be devoted to the training of army signalers, for it is when speed and accuracy can be relied upon that signaling proves so invaluable, and experience teaches that one is the accompaniment of the other. By the "Manual of Instruction in Army Signaling," a speed of five words a minute is necessary for qualification with flags, but it is found that the signaler who averages over seven words a minute is more correct than another who does not attain to that standard. With the heliograph a much greater speed should be insisted

upon, ten words should be the minimum allowed for qualification. From the earliest instruction signalers should be taught to work quickly, each letter being signaled at the uniform rate at which they will eventually be called upon to work; for beginners of course the pauses between letters can be regulated to suit the capacities of those under instruction, but if at first taught to signal and read slowly, they contract an imperfect style and disregard to time which is the essential of good signaling.

The training and practices should be made as interesting as possible, and all qualified signalers should have frequent opportunities of keeping up the knowledge they have acquired, periodical practice being necessary for a high state of efficiency. They should be exercised in detached parties sent out in different directions without any pre-arrangments, and instructed to find and open out communication with each other. During route marches, advance and rear guards should have signalers attached, whose duty it would be to avail themselves of every opportunity of communicating when advantages of ground offered. The men should be thoroughly conversant with the best kind of back grounds, which differ materially for heliographs and flags; for instance, a sky-line is the best for a flag, but the worst for a mirror. Careful consideration in the selection of back grounds will often save much time by avoiding the necessity of any subsequent alteration of the position taken up.

Staff of Signalers.—It would be almost impossible to lay down any hard-and-fast rule regarding the numbers of signalers that should accompany an army taking the field, so much would depend upon the nature of the country to be traversed both geographically and politically, and the disposition of the troops. In every instance the requirements would be subject to constant variation, and although 20 signalers might in some cases suffice for a force of 5,000, it is quite certain that the proportion this would give of four to a thousand would be inadequate. Roughly speaking, taking the numbers with the Khyber, Kuram, and Kandahar Columns during the first phase of the Afghan campaign, the proportion of signalers to fighting strength was as 1 to 250.

A memorandum from the Quartermaster-General's Office, dated Lahore, 11th December, 1878, states that "all the signalers are to be made over to the officer in charge of signaling, who will arrange for their pay, rationing, discipline, carriage, camp equipage, &c.;" this memorandum was issued after the force had crossed the frontier, and it was found impracticable, therefore, to carry out the instructions in their entirety. Lieutenant Savage, R.E., Kandahar Column, reports: "with this force the signalers have seldom been detached altogether from their regiments . . . . they are more comfortable than when entirely detached."

Perhaps a compromise between the two would answer best. There might be a permanent staff consisting of specially-selected expert signalers in the proportion of say 1 to 300 entirely under the signaling officer. He, however, would be in possession of the names and qualifications of all the other certificated signalers with the force, so that at any time when extra work had to be done, signalers could be drawn from regiments and detachments on the spot, who without being removed from their companies, could, for the time, give their services, and receive their signaling pay according to the periods of employment. It is very desirable not to withdraw men from the fighting strength of regiments unnecessarily, and this would often be the case if a sufficient number of signalers to meet all contingencies were kept as a permanency on the signaling staff.

Pay of Signalers.—During the Afghan campaign, the Government of India sanctioned extra pay to signalers, at the rate of eight annas for non-commissioned officers, and six annas for privates, per working day. This was most desirable, for not only were they generally kept employed, but the wear and tear to clothing and boots greatly exceeded that of their comrades. If not actually at work, they always had to be at their posts, for the success of signaling operations depends upon the careful look-out, kept so as to ensure a signal from any direction being promptly responded to. Formerly, then, it can hardly be wondered at that the position of a sig-

naler was not much coveted, but now that they receive remuneration, a high standard of efficiency should be exacted before a man receives a certificate of qualification. The responsibility of their duties should be impressed on them, and the strictest observance to the regulations laid down for the conduct of a signal station should be enforced. None but really first-rate signalers, and fairly educated men, should be entrusted with the charge of a station.

The heliograph does not yet form part of the signaling equipment of regiments at home or in the Colonies, and being of comparatively recent issue to those on the Indian Establishment, men are borne on the Signaling Rolls of their regiments irrespective of their knowledge of that instrument, and it happened when signalers were called for, some were sent to the front who had never been trained with the heliograph, and until they were taught their services were of little or no use. It is not a case of two heads being better than one, for one good signaler left entirely to himself will get through more work than half-a-dozen indifferent ones.

Mounted Signalers.—When troops are on the line of march mounted signalers should always be held in readiness and placed as circumstances may require, for in the event of any communication being necessary between, say, the advanced and rear guards or flanking parties, by the time Infantry Signalers had opened communication and despatched whatever business there was, the column would have moved on and they would be unable to regain their places without much fatigue, whereas cavalry men could push from point to point with ease and rapidity. They might also be most advantageously employed when a signal station happened to be some distance from camp, for not only would the dismounted signalers be saved harassing marches to and fro, but communication would be opened earlier of a morning, which is a desideratum. The brightness of the sky and power of the sun in the forenoon should be utilized to the fullest extent, for in a climate like India, just double the amount of work can be got through in the morning as is possible in the evening. Generally speaking, the sky becomes more or less cloudy after one o'clock, and stations bearing west appear surrounded with haze.

General Biddulph strongly advocates the employment of mounted signalers. With the Peshawur Valley Field Force signalers from a cavalry regiment accompanied all reconnaissances. From the 20th to 23rd March, 1879, they rode out to a height about four miles from Jellalabad and kept up communication between General Browne's head-quarters and General Tytler's force, which was destroying the towers of recalcitrant villagers in Maidanak. Again, on the 26th December last, a brigade marched from Cabul to Mir Butcha's forts in Kohistan, and by sending out a cavalry signaling post daily to the hills north of Sherpur communication was maintained with the brigade, although two ranges of hills separated them from the capital.

Screening Heliographs.—The work at a signal station is naturally subject to constant fluctuations, and it is when a number of messages pass along the line that the strictest superintendence becomes necessary, for if everything is not in good working order and discipline not enforced, the sun sets before perhaps half the messages have been despatched. Heliographic signaling requires the greatest patience. This should be impressed on men under instruction, for they are certain to have their forbearance and tempers put to the test. Either the light fails at a critical moment—the reader at the opposite station requires constant repetitions—he, in his turn, does not give the most favorable flash to read by—and so on; it is astonishing how many interruptions do take place, but practiced hands soon get accustomed to such vexations, and learn the value of time. However, notwithstanding every forethought and supervision, the press of messages is sometimes too great for the ordinary single line of heliographs, and when this is the case and the instruments are available, they should be doubled. This was done when General Roberts visited the Peiwar Kotal in February, 1879; the telegraph line was only then laid as far as Habib Kila, so a couple of instruments were set up at each station, one for despatching, the other for receiving messages, and by this means just double the amount of business was transacted as would other-

wise have been possible. To avoid confusion, the heliograph despatching was screened from the party despatching from opposite station and *vice versa;* the men reading at one station were not interrupted by seeing the answering flash of the party receiving at the other. A tree, rock, or the gable end of a hut became available to screen the instrument.

The flash from a heliograph is a reflection of the image of the sun and consequently has an angular diameter of 32′. The diameter of a disc of light increases with the distance from the mirror. At 107 yards the disc is one yard in diameter, and theoretically should increase one yard in every 107, but practically it will be found to increase very much more. This proportion would give only about 66 yards for a range of four miles, but the flash has been seen at that distance for 100 yards on either side of the signal station. Thus it might be necessary, in the event of an enemy being likely to decipher the signals, to screen the flashes from his view, and as this requires a little nicety it should form part of the instruction of signalers. On the other hand, the flash may have a discouraging effect on an enemy. It was generally considered by the Affridis that the heliograph was a mystic instrument by which homage was paid to the great Sun-God, his favor invoked, and the light of his countenance prayed for. This superstition was confirmed to their minds by the fact that snow, which usually falls in November, held off till February and extraordinarily fine weather prevailed, favoring the movements of troops and facilitating the collection of stores to an extent which, under ordinary circumstances, would have been impossible. And in December last when the Cabul force was temporarily shut up in the Sherpur cantonments, surrounded by the largest number of fighting men that have ever been assembled in those parts, heliographic communication took place between the garrison and Colonel Hudson's small force at Luttabund. The flash must have been seen by many of the tribesmen, warning them that the connecting links with the Khyber Division were still intact, and that the reinforcements would soon be pushed forward to put to flight Mahomed Jan and his followers.

In connection with the subject of screening flashes, it may be well to mention that when three signal stations happen to be nearly in a straight line and are all at work, the terminal stations will possibly be much inconvenienced by observing the flashes from two mirrors. A case of this kind occurred in the Kuram Valley last year. The Peiwar Kotal signalers worked with Habib-Kila and Kuram, both of which, although 12 miles apart, had the same bearing. The Kuram signalers could see the sheen of the mirror working to Habib-Kila as well as the flash of that directed on them. This was rectified by screening the heliograph from the station for which the messages were not intended.

Signal Fires.—There can be no doubt that the hill tribes of the N. W. Frontier carry on communication by signal fires. These beacons can be seen for such vast distances that it is possible the revolt which took place at Herat the day following the massacre of the embassy at Cabul was pre-arranged, and that the temporary cessation of British influence at the capital was by some preconcerted signal communicated across the hills.

It would be interesting to know if they have any particular code. Probably their signals are very limited and just arranged for the time being, still any system by which the simple intelligence "all's well" or the reverse can be communicated, is worthy of attention, and until a great improvement in the lamps in use with regiments takes place* signal fires might often be resorted to with advantage.

A curious case of night signaling was watched on the arrival of General Roberts in the Khost Valley in January, 1879. The Ameer's representative, Naib Akhram Khan, held the Matun Fort with levies which were not at first removed. The ex-Governor of Khost, with the usual treachery and dissimulation of his race, had assured the General that all was quiet and that the inhabitants were looking forward with joyful expectancy to the British Raj. During the first night a torch was carried round the ramparts presumably to acquaint Mongals and Khostwals that they still retained pos-

*Lieut. Whistler Smith, R. E., Superintendent Field Telegraph, reports that his experiments with Begbie's (C) pattern lamp were successful up to 25 miles.

session of the Fort, and Flashes, as if a handfull of gunpowder had been thrown on to a fire, were answered in a similar way from the hills. The events of the following day gave additional proof of the character for which the Afghan is so proverbial. No supplies had been furnished, and a cavalry reconnoissance drew the enemy, who were harbored in the surrounding villages. They sallied out on three sides of the camp, and as it afterwards transpired, looked upon the annihilation of the force and the general looting of the camp as a certainty. The tribes between the Khost and Kuram Valleys were ready to close the communications and actually seized a cavalry outpost at Yakoobi. It is needless to say that their schemes were frustrated.

Heliographic Chart of India.—It is probable that no perfect heliographic system could be established connecting the stations scattered over the plains of India, the country is so flat and the lower strata of the atmosphere as a rule so dense and murky, but there is no reason why the stations within view of the hills might not be connected, by making use of carefully selected points in the hills as intermediary; stations in the plains invisible to each other might thus be brought into communication. This would especially be the case in the Punjab and parts of the N. W. frontier. Signals between Chakrata (in the hills) and Roorkee (in the plains) have been read with the naked eye, and as they are 60 miles apart it is not improbable that with the aid of good telescopes many of the principal military stations could be connected. When opportunity offers it might be as well perhaps to institute practical experiments and have a clearly defined scheme drawn up which would bring as many as possible of the more important points into communication, so that in the event of any interruption in the telegraph line, the alternative means could be resorted to without delay.

The "Heliostat."—In the "Army Signaling Manual" an instrument called the heliostat is described, which differs from the heliograph chiefly in this particular only, viz., that instead of making the appearances and disappearances by a slight alteration of the mirror they are affected by raising or lowering a shutter which exposes and hides the reflecting surface. It is evident that this is a slow and laborious process in comparison with the rapid and simple motion occasioned by the slight pressure of a signal key. The reason for this modification of Mr. Mance's original instrument is that the action of the finger key disturbs the tripod, and alters the alignment. I can confidently say that during the whole time I have worked with the heliograph, and I have done so on every variety of ground, no such difficulty ever presented itself. If the instrument is properly set up, the alignment is easily made and as easily preserved, and the motion of the mirror either in signaling or adjusting does not interfere with it.

Conclusion.—It will be evident from what I have said that army signaling is likely to play a much more important part in warfare than has hitherto been the case. However old the use of mirrors may be for flashing, their employment for conveying verbal intelligence is of quite recent date. We hear nothing of heliograph messages in the American Civil War, the Prusso-Austrian, the Abyssinian, the Franco-German, or the Turko-Russian Campaigns, and we may perhaps accept this as sufficient proof that no such instrument was then in use. During the last two or three years, however, the heliograph has proved of such incalcuable value that its importance cannot be overrated. The evidence brought forward here may perhaps induce my hearers to concur in the opinion that the subject is well deserving the serious attention of the authorities, in order that the service may be provided with the best possible equipment, and army signalers encouraged to make themselves proficient in the art of heliography.

APPENDIX.

Notes on Construction of Signaling Apparatus.—A few remarks on the signaling apparatus and the component parts of heliographs may not be out of place.

Nearly all the instruments used in Afghanistan were of the regulation Roorkee pattern varying in details according to the date of issue. The mirrors ranged between $4\frac{1}{4}''$ and $5\frac{1}{2}''$ in diameter. Each column had in addition a $3''$ instrument supplied directly by Mr. Mance, and it was worked most suc-

cessfully between the Peiwar Kotal and Ibrahimzai—distance 30 miles. The tripods were, however, too light to withstand wind and rough usage, but in accordance with recommendations made at the time, they have since been constructed more substantially with metal plates strengthening the joinings of the legs with the center piece.

So many sizes and patterns have now been tested that it would be well if steps were taken to decide upon the most desirable. While, undoubtedly, the 5″ heliograph is the best adapted for general use, it would appear advisable that a proportion of 3″ instruments weighing only about as many pounds as should be available for reconnoitering parties and mounted signalers, and 8″ or 10″ for distant signaling. When the question has been carefully considered, great exactness should be observed in the manufacture of all the component parts so as to render them interchangeable. Some of the instruments in use with regiments in India were made at the Sappers and Miners Workshops, others at the Roorkee Canal Foundry, and the fact of the mirrors and various parts not being similar was often the cause of much inconvenience.

Sighting Arrangements.—When the heliograph was in its infancy, a sighting rod was set up about 10 yards in front of the instrument, and fitted with a metal stud which slid up or down until truly aligned with the distant station. In communicating, the flash was kept playing on the stud. This sighting rod was abolished in favor of a tripod, which serves to support quite a new form of sighting rod (or, when the position of the sun demands it, a reflector which is ingeniously adapted to serve also as a sighting vane). This second tripod is placed about 3 feet from the signaling mirror tripod; being made to interlock, both can be carried when packed as easily as one. But the instruments now issued to regiments in India are provided with a supporting arm which dispenses altogether with the second tripod. This arm, about 16 inches long, is clamped to the base of the instrument and serves to support the sighting rod, or, when occasion requires it, the reflector. The points for and against a supporting arm may be summed up as follows:

It dispenses with one tripod, consequently is more handy, saves a little in weight, and practically wherever a man can get a footing, the single tripod instrument can be set up. On the other hand it is alleged that a high wind driving against a mirror, placed at the extremity of a projecting arm, occasions a vibration that affects the steadiness of signals, as it makes the instrument top-heavy; a short arm necessitates placing the mirror at a less favorable angle for catching the sun, and thus causes loss of reflecting surface, while a long one increases the vibration, and, what is of more importance, adds largely to the size, weight, and cumbrousness of the box in which it is carried. The time required to set up and repack would probably be a little less with the supporting arm.

Horizontal Motion Screw.—For a long time the horizontal motion screw of the instruments manufactured in India was fixed to the signaler's right. This was well enough for a left-handed man, for he could regulate the flash with his right hand by turning the screw as the sun apparently worked round, while he signaled with his left. But as left-handed men are the exception, the position of the screw was condemned, and in the more recent issues, just before the Afghan campaign commenced, the screw was on the left hand side, thus suiting all right-handed signalers. In Mance's 3-inch heliograph (and I understand in all his instruments) the revolving plate and horizontal motion screw are so constructed that the screw can be placed right or left, which is of course a great advantage. This is effected by fixing the screw to the metal piece which fits on the tripod, and not to the base of the mirror. In the Roorkee patterns, the screw turns itself as well as the mirror round the tripod.

Mirrors.—Various methods have, from time to time, been adopted in India of securing the mirrors to their frames. When breakages occurred, it was remarked that those which were fastened with screws connecting the rim and frame, generally cracked from screw to screw, showing probably that the glass was pinched at those points. Some heliographs received from the Roorkee Canal Foundry had the mirrors secured with

out screws, a tight-fitting rim over the mirror seemed to keep it firmly fixed in the frame. Mr. Mance puts the mirror in at the back, padding it with a few slices of cork and then screwing on the thin backing of metal which rests on a flange in the rim and does not touch the glass. With this arrangement breakages are said to be extremely rare.

While on the subject of mirrors it may be useful to remember that glass can be cut under water with a pair of scissors. Spare mirrors were ordered to be sent to Kuram, but no mention was made in the indent that they were required for heliographs with screws fastening the mirrors between frames and rims. The mirrors arrived and the edges had to be cut to allow the screws to pass through, this was done by holding the glass under water and cutting it with a pair of scissors.

Telescopes and Stands.—A really good telescope and strong serviceable stand ought to be issued to regiments for the signalers, who should be practiced in their use and taught to read signals at long distances. As a rule, men strain their sight by trying to read with the naked eye instead of using a telescope, and a man is constantly seen delaying over his message by calling for more "light," when with the aid of a telescope he could read straight through without an interruption.

With the Kuram Force, the telescopes and stands were of all sorts and sizes, some large and cumbersome, others small and fragile; with regard to the telescope stands there were none that answered the requirements of supporting the telescope firmly in position and with the means of speedy adjustment in any direction. As a rule the men had to improvise rests, or place the telescope on rocks. It is very important that a signaler should be able to settle down comfortably at a telescope steadily fixed, when reading messages.

Sighting Vane.—The sighting vane proved the weakest part of the heliograph during recent trials on field service. The cross edges constantly became disconnected from the circular rim. The chains to which the silver discs were attached broke, and the discs were lost. It was difficult also to adjust the discs when the man's hands were cold. The sighting rod with the instrument supplied by Mr. Mance was far preferable, no part of it can be lost. The alignment is rapidly altered, for, being jointed, the vane can be raised or lowered or moved to the right or left, without shifting the tripod. The aluminium disc is permanently fastened to a strong steel shaft, and is of sufficient length to enable the signaler to see the shadow spot when the key is not depressed, *i. e.* the rise and fall of the shadow spot can be plainly seen while signaling.

Fastening of the Signaling Key to Frame of Mirror.—The signaling key in the Roorkee pattern is attached by a piece of metal and small screws to the frame of the mirror; these are quite unequal to the strain, and soon work loose. It should be screwed to the circumference of the frame where there is more metal to receive the screws.

Boxes.—All reports agree that the heliograph boxes are not sufficiently strong, and the cleats inside for securing the instrument, supporting arm, and sighting vane, sometimes broke or dropped out, but these and all other defects of the kind will no doubt be attended to in future.

Mance's cases are constructed to serve as a stand for the instrument, should the situation render it more expedient than the erection of the tripods.

Spare Component Parts.—The officer in charge of any signaling operations in the field should have a case fitted with spare mirrors, screws, springs, &c., and a few simple tools. Sometimes, for the want of such appliances, an instrument had to be sent to Roorkee for repair at a time when it could probably ill be spared.

Colored Spectacles.—A few colored spectacles should be provided, for the constant strain of reading signals when there is a glare or high wind is very trying. But signalers are not sufficiently careful of their eyes, and especially when using a telescope, they generally press the eyelid and eyeball of the closed eye with their fingers when looking through a telescope, instead of simply screening it with the hand hollowed in such a way that no portion of the eye experiences any pressure. They ought to practice reading right and left eyes alternately, so that the strain may not always be on one.

Message Books.—The new form of message book, with a division ruled for each letter, was universally condemned and the old pattern procured when possible; the signalers found great difficulty on a cold morning in keeping the letters within their limits and the messages were always more difficult to read than if they had been taken down in the ordinary manner.

THE power of absorption of heat rays by powders not mixed with any binding material has formed the subject of investigation by Herr Van Deventer. Under a copper cube kept at 100 deg. was brought a thermo-element consisting of a brass plate, on the lower side of which was soldered a parallelopiped of bismuth and antimony. On the plate was spread the powder to be examined. A second similar element, with thermo-element lampblacked, served for control. The results were: (1) Powdered substances in the same physical state have different absorptive power; (2) this depends on the thickness of the absorbing layer: each powder has its maximum absorption layer; (3) quite comparable values for the absorption cannot be had, as the thickness of the powder layer cannot be exactly determined; (4) the divergences proved in Tyndall's results with different binding materials are attributed to his not having taken into account the maximum emission layer; (5) whether the binding material affects absorption, and if so, how can it be demonstrated by the author's method—the element being painted over with the liquid holding the powder in suspension—but experiments are here wanting; (6) the author's series of powders arranged according to absorption is quite different from Tyndall's emission series.

EXPERIMENTS ON THE RESISTANCE TO HORIZONTAL STRESS OF TIMBER PILING.

By JOHN WATT SANDEMAN, M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

THESE experiments were undertaken to ascertain the amount of resistance opposed to the horizontal movement of timber piling by different strata, such as clay, sand, and forced material; also to determine the length necessary to be provided for, in back tie or anchor piles, with a view to economy in the construction of an extensive amount of river quayage. The results are recorded as affording a few practical data for elucidating these questions, in reference to which, so far as the author is aware, no experiments have hitherto been made.

For each experiment two piles were driven (Figs. 1 and 2) at distances of 20 feet apart, and slightly inclined from the vertical; one representing the front, and the other the back tie pile in an ordinary timber quay. The front piles were securely strutted to resist horizontal stress, the lower ends of the struts abutting against short piles. The back piles were free to move towards the front piles under the influence of the stress. The horizontal movement was measured from a plumb line at the levels indicated (Figs. 3 to 10), which show the inclination of the back piles in each case previous to the application of any stress. The measurements recorded in the lower columns of the table do not, however, represent the total distances through which the back piles moved. The actual distances at the same levels would probably be at least twice those given in the table, dependent on the depth below the ground at which any movement of the piles took place. In experiments Nos. 2 to 5 the back piles were pulled beyond a vertical line, as indicated by the horizontal measurements in the table being greater than those in Figs. 4 to 7.

The stress was applied at different levels between the piles by chain blocks and fall attached to each, the loose end of the chain being fastened to smaller blocks with a rope fall, the end of which was conveyed to a winch. The stress was registered by one of Duckham's 20-ton hydrostatic weighing machines.

The square piles were of Baltic red pine, the round piles of English forest larch.

TABLE SHOWING THE RESULTS OF EXPERIMENTS ON THE RESISTANCE TO HORIZONTAL STRESS AFFORDED TO TIMBER PILING BY DIFFERENT SOILS, ETC.

	Stress applied above Ground level	Stress applied near Ground Level.					Stress applied below Ground Level.	
	Experiment No. 1. Square Piles.	Experiment No. 2. Round Piles.	Experiment No 3. Square Piles.	Experiment No. 4. Square Piles.	Experiment No. 5. Square Piles.	Experiment No. 6. Square Piles.	Experiment No. 7. Square Piles.	Experiment No. 8. Square Piles.
Nature of ground.....	Clay	Loose ashes & clinkers	Ashes & clinkers to depth of 12′, hard ground below	Clay	Clay	Sand	Clay	Clay.
Length and diameter of piles.....	24′3″ × 12″ × 12¼″	26′ × 12″D. at ground level	20′ × 12¼″ × 12″	24′ 3″ × 11½″ square	16′ × 12¼″ square	24′ 6″ × 12½″ square	25′ × 12″ square	15′ 6″ × 12″ × 11½″.
Inclination of pile.....	1 in 10¾	1 in 29	1 in 12	1 in 10¾	1 in 12	1 in 9	1 in 11¼	1 in 12½.
Depth of pile in ground	15′	18′	15′	15′	10′	14′	(Original) 15′ (Forced) 5′6″	(Original) 10′. (Forced) 5′ 6″.
Height of pile above ground.....	9′ 3″	8′	5′	9′ 3″	6′	10′ 6″	(Original) 10′ (Forced) 4′6″	(Original) 5′ 6″. (Forced) 0′ 0″.
Level at which stress was applied, + above, − below, original ground.....	+ 6′ 6″	About + 6″	About + 6″	About + 6″	About × 6″	About + 6″	About + 6″ & − 5′ forced	About − 2′ and − 7′ 6″ forced.
Length and breadth of planks on back piles	....	....	....	....	....	....	Two planks 10′ long and 9″ wide	10′ long and 5′ 6″ in total width.
Position of planks.....	....	....	....	....	....	....	+ 5′ 6″, covered by forc'd material for 8′ in length	Top + 5′ 6″, fully covered by forced material.
Nature and depth of forced materials heaped against planking on back piles.....	....	....	....	....	....	....	Sand and ashes 5′ 6″ deep, and extending 9′ in front of piles	Sand and ashes 5′ 6″ above and 3′ below ground level, and extending 10′ in front of piles.*

*A trench 3′ deep was excavated in the line of the piles, to enable the stress to be applied lower.

The numbers in the columns below indicate the movement in the back piles under the influence of the stress, measured in inches, or described in the Paper.

Stress in Tons.	1st Trial.	1st Trial.	1st Trial.	2d Trial.	3d Trial.	1st Trial.	2d Trial.	1st Trial.	2d Trial.	3d Trial.	4th Trial.	1st Trial.	2d Trial.	3d Trial.	4th Trial.	1st Trial.	2d Trial.	1st Trial.	2d Trial.	3d Trial.
1.....	1¼	1¼	..	..	..	..	..	¼	..	..	..	..	..	..	..	..	1¼	..		
2.....	2⅜	..	..	..	..	⅛	..	¼	..	..	..	⅛	..	..	..	..	,,	..		
3.....	3	1¼	⅛	..	..	⅜	..	⅜	..	..	..	¼	..	..	..	..	,,	..		
4.....	Upon in-	1⅜	¼	..	..	½	..	⅜	..	..	..	¼	..	..	..	..	1⅜	⅛		
5.....	creasing	..	⅜	..	..	⅝	..	½	..	..	..	⅜	⅛	..	..	¼	1½	,,		
6.....	the stress	3½	1⅛	2¼	5	1⅛	..	⅝	..	..	..	½	¼	..	..	..	2	,,		
7.....	beyond 3	6	3¼	2½	..	1½	..	¾	..	..	5½	⅝	⅜	..	..	..	2¼	,,		
8.....	tons the	11	..	3¼	5¼	2⅛	4⅛	1¼	..	..	..	¾	⅜	..	..	1½	2⅜	,,		
9.....	pile yield-	After 8 tons	..	4½	5½	2⅞	4⅞	1⅜	2⅞	5⅜	..	1	½	..	..	1¾	2¾	,,		
10.....	ed, and	stress the	..	..	5⅞	3⅛	5	..	3¼	6⅛	..	1	⅝	..	..	1¾	3¼	,,		
11.....	came out	pile came	With 11 tons			4⅛	5¼	..	5½	..	8½	1	¾	..	..	2¼	3⅝	,,		
11½.....	of the	away so	stress the pile			..	..	..	6½	..	..	1	⅞	..	..	..	..	,,		
12.....	ground so	easily that	broke off at			..	7⅛	..	..	7⅞	9¼	1	1	..	..	2¾	4⅛	,,		
12½.....	easily as	no more	5′ 5″ below			..	..	..	..	8¾	..	1	1⅛	..	..	..	..	,,		
13.....	to prevent	stress	the ground			With 13		..	..	..	10	1	1⅛	..	..	With 13 tons		⅛		
13½.....	the con-	could be	level.			tons pile		..	..	..	12	1	1	..	..	stress the pile		,,		
14.....	tinuance	applied.	....			broke off		After 13½				1	1⅛	2⅛	..	broke off at		,,		
15.....	of the ex-	....	....			at 5′ 2″		tons the pile				1	2⅛	2⅜	3⅛	about 5′ below		,,		
16.....	periment.	....	....			below the		yielded so				1	2⅛	2⅞	..	the ground		,,		
17.....	....	....	....			ground		much that				1	2⅛	3	3⅛	level.		,,		
18.....	....	....	....			level.		no more				1	1	3⅛	3⅛	....		,,		
19.....	....	....	....			....		stress could				1	1	1	3⅛	....		,,		
20.....	....	....	....			....		be applied.				1	1	1	4	....		,,		
(Probably) 23..	....	....	....			....		....				When stress reached 20 tons it was removed, & the pile resiliated 1⅛″.				....		,,		
Weighing machine did not register above 20 tons, but index hand went beyond it.																		No more stress could be registered by machine.	Pile bent 1¼″ at ground level.	Pile bent 1¼″, which caused amount of forward movement to vary.

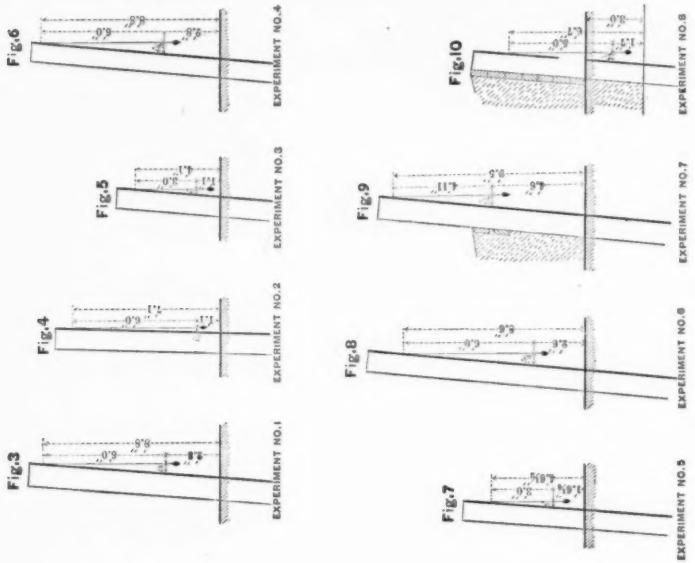


Fig.6
EXPERIMENT NO.4
Fig.5
EXPERIMENT NO.3
Fig.4
EXPERIMENT NO.2
Fig.3
EXPERIMENT NO.1
Fig.10
EXPERIMENT NO.8
Fig.9
EXPERIMENT NO.7
Fig.8
EXPERIMENT NO.6
Fig.7
EXPERIMENT NO.5

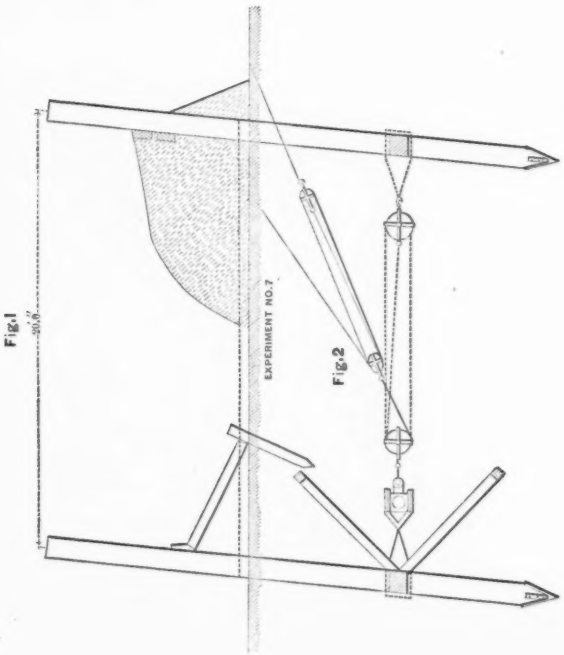


Fig.1
EXPERIMENT NO.7
Fig.2

The following data are afforded from the results of the experiments:

First. The amount of resistance opposed to the horizontal (or partially radial) movement of timber piling by different natures of ground.

Second. The variation in the amount of resistance which different strata oppose to horizontal movement—loose ashes affording the least, clay more, and sand the greatest amount of resistance, as instanced by experiments Nos. 2 to 6.

Third. The amount of increase in the resistance to horizontal stress obtained by planking upon tie piles, instanced by comparing experiments Nos. 4 and 5 with experiments Nos. 7 and 8.

Fourth. The length necessary to be provided for in back tie piles.

From the fact that three piles (experiments Nos. 3, 4 and 7), driven 15 feet into different strata, broke off at about 5 feet below the surface of the ground, it may be inferred that a tie-pile at a depth of about 15 feet into the ground would meet with as much resistance to horizontal stress (applied at the level of the ground) as if the pile extended to any greater depth.

THE DEPHOSPHORIZATION QUESTION.

From "Iron."

THE visit of the Iron and Steel Institute to Düsseldorf, and the opportunities generously afforded the members of observing the working of the Thomas-Gilchrist process at the Rhenish Steelworks and at Hoerde, have naturally tended to increase the interest felt in the important question of dephosphorization. It will, therefore, not be out of place to review briefly the present relative position of the basic and the acid processes, which are about to engage in a severe and protracted struggle—the one for supremacy, and the other almost for existence.

As Professor Tünner said, the chemical problem has been definitely solved, and although chemists may differ as to the exact course of certain reactions, the fact remains, that with proper care and attention, what has hitherto been regarded as the commonest of forge pig may be converted into good steel by the Bessemer process. If there were no greater difficulties in the manipulation of the basic than of the acid process, the immediate future of the old Bessemer trade would be very gloomy. As far as can be seen at present, however, certain conditions must be strictly observed in carrying out the former, in order to insure uniformity in the quality of the metal produced; and these conditions cannot be fulfilled without incurring extra expense. It is, no doubt, probable that, in the course of time, material reductions will be made in the working of the process; but, still, it must be confessed that there is no likelihood that, given a phosphoric pig on the one hand, and a non-phosphoric pig on the other, at the same price, steel will ever be produced as cheaply from the former as from the latter. This being so, the question may be stated as follows:—Can the cost of hematite pig iron ever be so reduced that the difference between it and the cost of phosphoric pig shall not exceed the extra expense of converting the phosphoric iron? The advantage of the new process is entirely centered in the cheapness of the raw material, and, therefore, needs no further comment. Its disadvantages demand more careful examination.

Mr. Massenez concluded the valuable paper which he read before the Institute by enumerating some of the items to which special attention must be paid in carrying out the basic process—at all events with white iron, which, he says in another place, "is, for many reasons, the most suitable quality." The first of these items is—Hot melting in the cupola. That is, the iron must enter the converter in a thoroughly fluid condition. In second melting there will, of course, be no difficulty here; but how will the direct process be affected, the advantage of which, in point of economy, is now

almost universally admitted? It was stated at the Düsseldorf meeting, that a special pig made expressly for the basic process, and containing scarcely more than traces of silicon, but nearly three per cent. of phosphorus, and over one per cent. of manganese, ran very hot from the blast furnace; but we must be allowed to express considerable doubt as to white pig iron running with the requisite fluidity, unless it contains a very appreciable quantity of manganese. The fluidity of the pig is a two-fold necessity; in the first place, to enable the blast to pass freely through the metal in the early stage of the process; and in the second place in direct working, to avoid heavy skulls in the ladle, which would be a very serious source of waste. It frequently happens, as any one acquainted with the routine of an iron-works will admit, that a stoppage or hitch occurs between the tapping of the metal into the ladle and its transfer from the ladle into the converter. With ordinary hot Bessemer pig a stop of half an hour matters comparatively little; but with white iron containing even 3 per cent. or 3½ per cent. of phosphorus and manganese, such a delay would be far more serious. If, however, an average of 1.5 per cent. of silicon could be allowed in a pig of medium grayness, this difficulty would doubtless disappear to a considerable extent. But silicon, in the basic process, must be considered as great an impurity as phosphorus, if not more so. If direct working has to be abandoned, it will prove a very serious drawback to the new process. The other items to which Mr. Massenez draws attention, viz., the addition of hot, well burnt, lime, and an increased pressure of blast tend to augment the cost; but they present no technical diffiulties. It is also generally thought that the basic process will, for producing the same grade of steel, require a larger proportion of spiegel or ferro-manganese, and with this must be associated the reincorporation of a certain quantity of phosphorus reduced from the slag, the removal of which before the addition of the spiegel, has not yet been satisfactorily carried out. Any overblow, *i. e.*, any prolongation of the afterblow beyond the exact point, will result in the development of a larger amount of carbonic oxide on adding the spiegel, and as a natural consequence, the danger of further reduction of phosphoric acid will be increased.

We will next consider the question of sulphur, which, in the present phase of the process, seems to be its greatest enemy. Sulphur is no doubt eliminated in a great measure, and the course taken by the sulphur line, sketched out on a diagram, is somewhat similar to that taken by the phosphorus. No trace is eliminated until the process is far advanced; in fact, it first of all increases in proportion to the metal as other impurities are diminished, and even when the afterblow is completed, there still remains in the metal a very appreciable quantity—about one-third of the original amount. In two charges, quoted in Mr. Massenez's paper, the actual proportions were 31 per cent. and 33 per cent. Mr. Thomas, in the course of the discussion, gave 0.4 per cent. of sulphur as the margin, which should not be overstept in the pig. Now, although very good rails may be, and in fact are, constantly rolled with 0.13 per cent. of sulphur; still, for the higher qualities, such as boiler plate, so large an amount could hardly be tolerated; at least such is the opinion that has frequently been expressed at the meetings of the Iron and Steel Institute, by gentlemen who have been foremost in promoting the use of steel in engineering work. There are two ways in which the sulphur difficulty may be met; and it is simply a question of cost. Firstly, by reducing it in the blast-furnace and, secondly, by overblowing the metal. Practically speaking, lime alone will scarcely suffice to eliminate the sulphur in the blast-furnace—when working on white iron—and another agent, manganese, will have to be called into play. It is not for one moment denied that the sulphur can be got rid of by surcharging the burden with lime; but blast-furnace managers will agree that a highly basic slag, such as would be required, would, in the face of the low temperature necessarily prevailing in the production of white pig, be a constant element of trouble in the working of the furnace. The blast furnace is always subject to slight variations, from causes too well known to need enumeration. In the manufacturing of gray pig we have

always a margin of temperature, but in making white we have not, and any unforseen stoppage of stove or boiler power might, with a highly basic slag, lead to difficulties of a serious nature, more especially with the direct process. In all probability, therefore, the extra cost of a small proportion of manganiferous ore will have to be faced in those districts, such as Cleveland, where the iron ores do not contain an appreciable quantity of this element. As regards the overblow (as distinguished from the afterblow) the sulphur can doubtless be removed in this manner; but this involves a loss of yield, combined with an increased proportion of spiegel, which further adds to the danger of reabsorption of phosphorus. The former course seems, therefore, far simpler, and certainly cheaper, and is the one which will probably be followed.

In addition to the points already mentioned we have to take into consideration the extra cost of the basic lining, basic additions, increased dead charges, &c., arising from reduced make, or the alternative of more extensive plant, to turn out an equal amount of work. At present, Bessemer pits, where the basic process is in operation, do not work continuously; but only by day, for instance, the night turn being occupied in repairing—such was the case at the Rhenish steel works—or, as Mr. Thomas admits, with present appliances, a vessel must stop for two or three days every fortnight or three weeks to undergo the necessary repairs. It would, however, be manifestly unfair to charge the new process with all this cost, because when new plant is brought into operation, arrangements will be made for changing the vessels as required, which, will of course increase the charges on account of capital, although to a far less extent than those incurred by the use of existing plant. Professor Tünner, who has given much attention to the economical side of the question, estimates the extra cost, taking the average of the Austrian works, at about 20s. per ton; but for England this estimate is probably far too high, and as far as the items here involved are concerned, something between 12s. and 15s. per ton will probably be nearer the mark—according to local circumstances. But in Professor Tünner's estimate there are two points which are not mentioned, viz., the difficulties in the way of running the iron direct from the blast furnace, and the cost involved in keeping down the sulphur, which will have a material influence on the ultimate result of the process. The probability is that the basic process will be a far greater success on the Continent than in England. In Westphalia, where the interest is at present centered, there exists ores containing both phosphorus and manganese, and which will be more suitable for the production of the new Bessemer pig than Cleveland ore, and in Westphalia and the East of France, the difference between the cost of hematite and phosphoric pig is considerably greater than in England.

South Wales, however, with its chead fuel, and Barrow, with its cheap ore, should be able to withstand the attack of the new process for many a long day. As the success of the new method increases, so will the value of pure ores decrease. Spanish ore has been sold in Bristol Channel ports at very little over 13s. per ton, and Algeria, with its marvelous deposits of the richest and purest ores, and with the improvements that will certainly be made in the development and working of the mines, and in shipping accommodation, will, when the pinch comes, be in a position to supply the South Wales ports at far lower prices than have ever yet been reached. That the Thomas-Gilchrist process will, in course of time, become practically successful in some districts scarcely admits of a doubt; but it will probably be many years before Barrow and South Wales cease to produce Bessemer steel in as large quantities as at the present time.

THE method of managing railway wagons with hydraulic capstans, well-known in this country, has been definitively adopted in France by the Campagnie du Nord, after ten months' trial, at the station of La Chapelle. The system seems to have been only once tried before (at Bercy station), but was given up for reasons unknown. The *Société Hydraulique* is charged with setting up the necessary apparatus, which is to be ready by the end of next month.

COMPRESSED STEEL.

From "The Engineer."

THE paper read at Barrow-in-Furness by Mr. Davis, of Westminster, on the compression of steel by the Jones process, as carried out at the Edgar Thompson Steel Works, in the United States, attracted a great deal of attention. The process, as modified by Mr. Davis, has been adopted experimentally at the Barrow Steel Works, and other firms are also, we understand, fitting up plant to try it. The idea of compressing molten steel to get rid of gas bubbles is not a new thing. Many years have elapsed since Sir Joseph Whitworth first practiced the art; and in Styria, at Neuberg, elaborate machinery was fitted up, at least ten years ago, to compress steel by hydraulic pressure. The plant required has, however, hitherto been very costly, and grave doubts have been entertained as to whether any results, and what results were to be had. The Jones process, however, dispenses with costly plant and opens up new possibilities; and steel makers who might well hesitate to invest £20,000 in an experiment, do not hesitate at all to spend a twentieth part of that sum on a small high-pressure boiler, and a few score feet of copper and iron piping. It is said that the Jones process has been quite successful in America. It is also said that it has been successful here. The contrast between it and the Whitworth process is so startling, that it is difficult to frame any consistent hypothesis to explain what takes place in the ingot mould. When two such eminent authorities as Dr. Siemens and Mr. Snelus differ in their explanations of the theory of the process, it is not too much to say that much remains to be explained. In a word, steel which has always been the most puzzling metal in existence, is determined to maintain its character, and has presented the world with a new problem, which may remain for some time unsolved. Let us consider for a moment what the problem is.

Sir Joseph Whitworth maintains considerable reticence with regard to several details of the practical working of his process, but, broadly stated, that process consists in forcing down a plunger or ram, by hydraulic pressure, on the molten steel when in the mould. He employs very high pressures; as much as two tons to the square inch, and more. Let us, for the sake of simplicity, suppose that he is dealing with a cylindrical ingot 10in. diameter and 5ft. high. The total pressure applied to the top of the molten metal will be about 150 tons or 160 tons. This pressure will presumably be diffused through the whole ingot while it is fluid, and it may be assumed that if any gas bubbles existed in the fluid they would be compressed; but however much compressed, they would still retain some dimensions, and there would, accordingly, be small blow-holes left in the ingot. But in practice no such blow-holes are found. At the Barrow Shipbuilding Works is now being erected a very large lathe. It will weigh 120 tons complete. All the gearing and shafting in this lathe is of Whitworth's compressed steel. Last week we made a careful examination of this gearing, and it may be pronounced to be absolutely without a flaw or a speck. To the back of a large face-plate is bolted a ring, in one piece, of internal and external teeth. The ring is some 6ft. in diameter, and the teeth are about 7in. long and 2¼in. pitch. It is impossible to find a flaw in it; and the ring has been machined. The contrast between this gearing and that used by makers of traction and ploughing engines is enormous. It is well known that to get from Sheffield firms a cast steel pinion without holes in which the end of a pencil can easily be put, if not the finger, is very difficult indeed. But in this lathe, as we have said, the pinions and wheels alike are entirely free from blemish. We cite this to prove that by the Whitworth process the cavities due to the presence of gas are not diminished in size only, but entirely got rid of. What becomes of the gases, which are apparently hydrogen and nitrogen? It is almost impossible to see how pressure can squeeze

out the gas, and yet be maintained in the mould. But, going a step further, we are presented with a new phase of the problem. It appears to be extremely doubtful that while the steel is fluid any bubbles of gas whatever are found in molten metal. The steel as it runs is quite as fluid as water, if not more so, and the gases, by reason of their levity, ought to rise to the top and escape, and it is quite certain that carbonic acid and carbonic oxide do thus behave. According to one theory, the hydrogen which makes the mischievous bubbles is only given off when the metal is solidifying; but if this be so, as the pressure is no longer diffused through the mass, but produces only direct vertical strains, how can it operate to prevent hollow spaces, which must be closed in from the sides, if at all, as well as from the top? Nor is this all. If Sir Joseph Whitworth states that he cannot get on without pressures of as great as two tons per inch, and even very much more, how is it that good results are obtained with pressures of as little as 80 lbs. and 100 lbs., while it is even assumed, and not without reason, that 300 lbs. of steam may do all Sir Joseph accomplishes? These questions are of very great interest indeed, for it will be seen at once that if solid castings can be made from the Bessemer converter, things will be rendered possible in mechanical engineering which are impossible now. But no such castings can be made at a moderate price, if at all, by the Whitworth system.

Mr. Jones has used steam at the Edgar Thomson works. We illustrated his apparatus last week, and when Mr. Davis' apparatus, now being tried in this country, is perfected we shall illustrate it. But is steam the best thing to use? No decided answer can be given to this question. Mr. Davis contemplates the use of air; but the cost of a compressing plant will be very much greater than that of a boiler. The great charm of Mr. Jones' system is its cheapness and its simplicity. The moment we depart from the use of steam, and adopt compressed air in its stead, complications and difficulties and expense will be incurred. In pursuit of simplicity, Dr. Siemens, we believe, tried to inject water on the top of the ingot in the mould, beneath, of course, a closed lid, and, if we are not mistaken, Mr. Jones tried the same device. In each case explosions resulted, as might have been expected. But the moment it has been proved that pressure will give solid ingots, no matter how that pressure is applied, various devices may be used to secure the required end. To us by far the most promising scheme seems to be the following: Let each ingot mould be made with a tight-fitting lid which can be readily and quickly put on. Then, as soon as the mould has been filled, let a measured quantity of some gas-producing material be thrown in on the top of the fluid steel and the lid put on. It would be by no means difficult to scheme a safety-valve arrangement, if such a thing were necessary, which it is not. A very few experiments would suffice to determine the quantity of gas-producing material to be used, and its nature. We may suggest one or two. Nitrate of soda and clay made into a cake would give off gas slowly; oil worked up with clay would have the same effect. Even common coal coated with clay by dipping it in a thick "slip," would probably answer the purpose thoroughly. Roughly speaking, coal will give off about 250 times its own volume of gas at atmospheric pressure. At the temperature of molten steel its volume would be probably about 1500 times that of the coal. If there were no leaks in the mould a cubic inch of coal would be ample to give a pressure of some 300 lbs. or so on the square inch. The clay in all cases serves the purpose of keeping the gas-producing material cool for a few seconds until the lid can be put on the mould. The process would be to the last degree simple and inexpensive. It would suffice to throw into each mould, as we have said, a pellet of gas-producing composition, enveloped in clay, and to put on and secure the lid; no costly apparatus of any kind would be needed. The scheme is not patented, and it is open to the whole world to try. It is also worth while to consider whether the adoption of some method of agitating the mould, as by letting it drop vertically and suddenly, though a few inches, just before consolidation begins might not operate powerfully to dis-

engage gas, without any other agency whatever.

Whether the Jones, or the Davis, or the process which we have suggested, be employed, the thing most wanted now is an air-tight lid for the ingot moulds which can be made tight at a moment's notice. The mouth of the mould is protected by a loose plate while the ingot is being filled, and there is a comparatively smooth and clean surface on which the lid can rest, but some kind of packing which will stand a high temperature is essential. Several packings have been proposed; one is a ring of asbestos interposed between the lid and the mould, another is simply a flat coil of copper wire. How the problem may be ultimately solved we cannot say, but we can say that, until it is solved, the Jones system cannot command success. The lids of the moulds used at the Barrow Steel Works, in the experiment made last week, leaked steam so profusely that it is doubtful if there was more than 70 lbs. or 80 lbs. pressure in the mould, although there was 180 lbs. in the boiler. It must not be forgotten that the steam is highly superheated and that while in this condition it will escape readily through orifices which permit but an infinitesimal leakage of saturated steam.

ATLANTIC CABLES.

From "Engineering."

When the first Atlantic cable was laid in 1858, each step in the operations was carefully reported in the daily press, and eagerly perused, owing to the novelty of the work and the intense interest it had aroused in the public mind. In the same way, though perhaps to a less extent, the operations of 1865 and 1866 were made public. In 1869, the cable laid between Brest and St. Pierre, known for some time as the French Atlantic, caused less interest. The cables of 1873 and 1874 were but briefly recorded, and the cables laid last year and this year have scarcely been noticed at all. This is partly due to the rivalry existing between the two telegraph companies, as well as between the firms who have made and laid the cables. Very little information is to be obtained on the subject from the principal persons concerned in the work, who, it would appear, wish to have as little made public as possible for fear of their adversaries gaining some advantage by it. This appears to us excessively childish, for any persons having sufficient interest in gaining particulars of either work, to be willing to incur a small expense and trouble, might easily obtain all the information he desired concerning the cables and operations. The rival parties themselves are not likely therefore to have any difficulty in knowing all that occurs in the enemy's camp, and it is only the public, and those who take an interest in the subject generally from a technical and scientific point of view, who are deprived of the information as to what is being done in this branch of engineering. There may be some slight advantage to contractors in thus keeping all experience and information as much as possible to themselves, but we doubt very much whether this exclusion of all, except those who are actually employed on the work, from any information as to the progress that is being made, is beneficial or will tend towards the advancement of telegraphic engineering generally. Improvements and new ideas do not always come from rich, conservative, and exclusive bodies or corporations, and unless what may be termed outsiders hear a little of what is going on, it is unlikely that they will turn their attention to improvements.

That an improvement on the type of cable employed on the Atlantic in 1865 and 1866, and which is known amongst engineers as "Atlantic type," is required is proved by the fact that these cables had only lives of about 8½ years, and if cables will only last that time, even 10 per cent. dividends will not pay for them, whereas most cables at present only pay about 6 or 7 per cent.

The type we allude to consists in ten homogeneous iron wires, each separately surrounded with strands of Manilla hemp, as the mechanical structure round the jute-covered core. This type of cable, when new, is, of course, excellent

for the process of laying. It has a low specific gravity and great friction from the roughness of the Manilla hemp, and can, consequently, be laid with a given amount of slack with a very small strain during the operation of paying out. But as regards its durability it has little to recommend it. The wires being separated allow insects easily to enter. The hemp rots, and the iron rusts away. The 1873 and 1874 cables had a little hemp and pitch and silica layed on round the whole, and have thus an additional protection, but the coating was meager.

The cable laid by Messrs. Siemens last year we believe consists of homogeneous iron wires touching one another, thus returning to what has been known as the Mediterranean type of cable, the iron being protected from rust by two coatings of yarn, pitch, and silica round the whole cable.

The cable laid this year by the Telegraph Construction Company has ten homogeneous iron wires, each covered with a thick coating of preservative compound called Clifford's compound, the composition of which is kept secret, and these are each separately further covered with tape. Between each wire a strand of hemp is placed. The whole cable thus formed has two layers of tape and pitch compound outside all. The mode of combining hemp and iron alternately round the core has been before largely adopted by the Telegraph Construction Company, and was first, we believe, employed on the cable between Sydney and New Zealand. We do not know what advantages are claimed for this plan, but it would appear to us to be principally a mode of saving first cost, by substituting hemp for iron at the expense of durability. It does not seem possible that the hemp can take any strain properly with the iron, and when the cable gets old, we should think the hemp would not keep the wires in place when the cable is being strained or bent about in repairs, so well as hemp round each wire. It is cheap, and that is all that can be said for it. The strong outer coating of tape and pitch no doubt keeps the wires in place when the cable is new, but we should look to what will be the state of the cable when this outside coating of hemp is gone. When the hemp has perished considerably it seems clear that the wires with wide spaces between them, like a birdcage, will not in the least fulfill the conditions of a wire rope, and we shall be very much astonished if, after a few years of experience at repairing, this type of cable, with alternate wire and hemp, is not abandoned as a mistake. The attempt to preserve each wire with a compound, whatever it may be, is a step in the right direction. Gutta-percha applied in the ordinary way round wires for protection was proposed and patented by Mr. Samuel Statham in 1857. We do not know what Clifford's compound is, but we doubt whether it is better than gutta-percha, though perhaps much cheaper.

As regards the process of paying out there was one novelty in the Siemens expedition which we will describe. It is necessary, in order to distribute the slack of a cable uniformly, or in such places as the engineer may decide on, to know at every half hour the exact position of the ship over the ground. To do this by observations, even in fine weather, is only possible once every twenty-four hours, and when the sky is overcast not even then. Dead reckoning is not to be trusted on account of currents. The following plan was adopted therefore, and forms one of the latest novelties in cable laying: a steel pianoforte wire was paid out throughout all the deep water passage with sufficient tension to insure its being laid without any slack, and thus the distance actually run was measured and known at every minute. The wire was, we believe, in fifty mile lengths on drums, and the lengths were rapidly joined by a hook joint.

In paying out the Anglo-American cable this year two ships were employed, the Scotia and Seine, and when the Scotia had nearly finished paying out her length the cable was made fast to a buoy at some fathoms from the end, the stray quantity being coiled into a lifeboat, and the end thus handed to the bows of the Seine. In laying the Siemens cable last year there was a similar change from the Faraday to the Pouyer-Quertier.

It seems a pity that these operations are not published in detail, as they both no doubt reflect credit on those who have conducted them, and would be of great interest to all who follow up the important question of Atlantic telegraphy.

THE BELGIAN SYSTEM OF SHAFT SINKING.

From "Design and Work."

THE process is known as the Kind-Chaudron system of boring large pits, and takes its name from those of the two gentlemen whose combined inventions have produced it. One of them is M. J. Chaudron, a Belgian mining engineer, and the other, Mr. Kind, is a well known German engineer and sinker of artesian wells. M. Chaudron is the originator of the most important feature of the system, which is known as the "tubbing" of the shaft, and Mr. Kind is responsible for the mode of drilling. The sole object of the invention is to avoid the enormous expense which is involved in piercing through strata where water is lodged in such quantity that elaborate pumping machinery is required to keep the boring in a workable state. In England water-bearing strata have not been met with to a serious extent, but in France, Belgium, and other parts of the Continent, it has long been a source of annoyance that rich coalfields could not be reached, owing to the practical impossibility of penetrating with success the water-logged strata. It has frequently happened that years of toil and vast sums of money have been fruitlessly expended in the effort to combat this obstacle. The necessity of some means of eluding the difficulty evoked the scheme of Messrs. Chaudron and Kind, and it has proved in the highest degree successful. The principle upon which their plan is founded is to effect the sinking of the shaft without being compelled to remove the water, and afterwards to dam up the places where the water obtains ingress. The mode of operations will be best understood if shown in connection with the Whitburn Winning.

It is several years since the Whitburn Coal Company undertook the sinking of a shaft close to the sea shore, rather more than half a mile south of Marsden Rock. By the ordinary process they reached a depth of 109 feet, and then they came upon the water-bearing strata. Continuing the work on the old-fashioned style they sank 36 yards further. In doing so, however, the expense involved was enormous. They encountered "gullets" in their progress, from which the influx of water was so great that even a pumping power of 12,000 gallons per minute was incapable of contending against it. Accordingly, the ordinary mode of sinking was abandoned, and the directors determined to make a trial of the Kind-Chaudron scheme. On September 26, 1877, boring on the new style was adopted, and on January 4, 1879, the shaft, so far as the chief difficulty was concerned, was completed. The distance thus sunk by the ordinary process had been 52 yards, 2 inches, and by the Kind-Chaudron process 72 yards, 1 foot, 10 inches. This brought them below the water-bearing strata, and the sides of the shaft having been tubbed, so as to keep back the water, the sinking could proceed in the ordinary manner, which is more expeditious than by the German engineer's method. The total depth of No. 1 shaft now is 241 yards, but the sinking is not yet completed. The first workable seam of coal was met with at a depth of 202 yards, 2 feet, 4 inches. This seam was 8 feet, 9 inches thick, but it was not pure coal right through. A second seam of very good coal, 5 feet 2 inches thick, was met with at a depth of 228 yards, 2 feet, $1\frac{1}{2}$ inches, and a third, 3 feet $1\frac{1}{2}$ inches thick, was found seven yards lower. The seams of which the company are in quest, however, are the Maudlin and Hutton seams, and consequently the deepening of the shaft still continues. In proceeding with the sinking of the No. 2 shaft, the water-bearing strata was encountered at exactly the same depth as in No. 1. Profiting by their previous experience, the company at once brought the improved boring process into requisition. By means of the latter they have now attained a depth of a little over 274 feet, 164 feet 8 inches of which has been bored by the machinery inspected. A depth of 380 feet will have to be reached before sinking operations on the ordinary plan can be resumed.

We now come to the manner in which

the boring is conducted, and the plan pursued at the Whitburn pits is almost exactly similar to that followed in all borings by this process. When the water-bearing strata is reached, the first thing done is to lower a trepan, or drill, which will make a bore-hole of (in the case of Whitburn) 6 feet 7 inches in diameter. This trepan, which weighs eleven tons, is armed with a line of well-shaped teeth or chisels, firmly keyed into the superincumbent mass. Each of these teeth weighs about 3 cwt. The trepan is suspended by thick wooden rods from what is called a *balancier*. The latter is a massive braced timber beam, to one end of which the top of the topmost connecting rod is attached. The *balancier* moves after the fashion of a cradle. By means of steam power, one end of it is pulled down, and the trepan lifted a distance of four or five feet above the bed through which it has to bore. Then the steam cylinder is suddenly exhausted, and the trepan falls with immense force upon the stone, and its strong teeth cut into it at every stroke. Of course the trepan must not be allowed to strike continually into the same place, and a number of men are therefore stationed upon the platform which boards over the mouth of the shaft to give it a turn of an inch or two after every blow. After a certain amount of the stone has by this means been removed, the trepan is hauled out of the shaft, and a large tubular-shaped instrument, called a "spoon," is lowered into its place. It sinks into the loose material, which at once fills it, and the latter is prevented from falling out by two doors, which, as they only open upwards, allow the debris to get in, but, closing as soon as the hoisting begins, hinders it from getting out again. This process is continued until perhaps the total depth to be bored is reached, and then the large trepan is brought into requisition. The last-named, which weighs about 20 tons, works upon the same principle as the smaller one. Its duty is to increase the diameter of the hole from 6 feet 7 inches to 15 feet 5 inches, and it chips its way downwards in the same slow but effective fashion as its predecessor. The debris which it knocks off falls to the bottom of the small bore-hole, but there it is caught by a "cuiller," a tubular iron vessel which holds about 12 tons of the rubbish. The latter is hauled up and emptied as soon as it is filled. The explanation of the mode of boring and the watching of the operation of withdrawing the trepan and the "cuiller" made up almost the whole of the programme. At a quarter-past two the boring process was seen in operation. At half-past two boring ceased, and the work of withdrawing the trepan was begun. An hour was occupied in doing this. The trepan was hanging upon five or six rods, some of which were about 60 feet long, and as the lower extremity of each of them emerged from the shaft, the top of its successor was made fast to the cross beam on the platform before mentioned, and while the trepan with the remaining rods was thus hanging, the rod already out was hoisted away, after which the process was repeated until the trepan itself came up. The rods had to be joined together in the same way in order to get a sufficient length of them to reach the cuiller, and in the hauling out of the latter the method employed in taking up the trepan had to be followed. This procedure occupied, therefore, nearly two hours. It will be seen, consequently, that the progress made is very slow. In No. 1 pit the average rate of advance was with the small bore 2 feet 8 inches per day of twenty-fours, and with the large bore 1 foot 4 inches per day. In No. 2 shaft the average progress so far has been 1 foot 8 inches per diem with the small bore, and 1 foot 6 inches daily with the large bore. Every advance of about ten inches fills the cuiller, and necessitates the protracted process attendant upon its withdrawal and reinsertion. In this mode of working the water in the shaft is not a disadvantage, but an absolute necessity. It softens the rock upon which the trepan works, and allows the debris to be more readily collected and removed. It is, therefore, never interferred with from the time the boring commences until it finishes. As showing the advantage of this method over the extensive pumping system, it may be mentioned that fifteen men are sufficient to conduct the whole of the work connected with the sinking.

This way of piercing through the

moist portion of the earth would have been of no value, however, minus the system of "tubbing" invented by M. Chaudron. When completed, this "tubbing" has the form of an immense metal tube, which is lowered into the shaft and serves as a wall to keep back the water. As it would be impossible to construct above ground a tube over 70 yards long, 12 feet in diameter, the walls of which are from 2 inches to 3 inches thick, and which weighs altogether perhaps more than 1,000 tons, and then place it bodily in the shaft, another plan has to be adopted. This is, first of all, to construct a water-tight bottom, and build upon it the first ring of the tube. Thereupon it is set upon the water in the shaft, and it floats. Sufficient water from that lying in the shaft is put into it to cause it to sink a few feet. Then the next length is added to the tube, and it is sunk down again. Thus the tubbing is gradually built, while it floats all the time in the water, until at last it has attained such length that it rests upon the solid bottom of the shaft. The water is afterwards pumped out of the tubbing, and the false bottom removed. By fixing a bed of moss underneath the edges of the tubbing where it rests upon the bottom of the shaft, the water is hindered from passing underneath. The next thing to be done is to fill up the space between the outside of the tubbing and the walls of the shaft with cement. It will have been observed that the diameter of the shaft bored is 15 feet 5 inches, and as the tubbing will be only about 12 feet in diameter, a space of 3 feet, is left to be filled up. When this is done the shaft is completely water-tight, and then the sinking operations through the hard dry material below the water-bearing strata can be proceeded with expeditiously. This process has been adopted with the most complete success in France, Belgium, and Prussia, and about 40 pits have been sunk with its aid, the cost in all cases being exceedingly small compared with the expenditure incurred under the former system. The first trial of it in England was made at Cannock Chase, in Staffordshire, but there, through some mishap, the tubbing broke, and the work is not yet completed. The No. 1 shaft at Whitburn New Winning is therefore the first in England that has been sunk with success by the process. The invention is as simple as it is unique, and as admirable as it is ingenious, and the study of its details afforded both benefit and enjoyment to the large number of gentlemen who took part in the excursion.

OLD SANITARY LESSONS REVIEWED AND NEW LESSONS CONSIDERED.*

From "The Builder."

Sanitary science may be said to be both old and young. It is so old that we know nothing of its commencement, simply because we know nothing definite of the origin of the human race. The cave inhabitants were skilled in art; but at how distant a period they lived, or in what other respects they were skilled, we have little means of knowing; of this, however, we may be certain, that they would suffer from disease, and would use medicines and enchantments in some form to relieve their suffering.* At whatever period of this earth's history intelligent man appeared, diseases would afflict him; and when remedial measures were invented and applied, then *sanitary science commenced.*

There are problems in natural history which can only be speculative; as, the origin and constitution of matter; the origin of life; the origin of disease. The human intellect is powerless to fathom

* From a paper by Mr. Robert Rawlinson, C.B., read at the Exeter Congress of the Sanitary Institute.

* There are dwellers in caves at this day in parts of Great Britain and Ireland, as, also, in other parts of the world—probably as many as ever in any age occupied such places for residence.

these profound mysteries, and if revelation is rejected, there can be nothing but a blank impenetrable darkness. There is minuteness below the search of the best microscope, and a range in magnitude very far beyond the combining power of the best telescope. One law alone is clear and certain, namely, the universal law of motion, which is change—combination and disintegration—these never cease. That we call life or death pervades the universe; and the life of a system—sun and planets—though extended to millions upon millions of years, is, in the roll of eternity, no more than the life of an emmet, which is born and dies in a summer's day. As old systems perish, new systems replace them, to run their appointed course from birth to maturity, and from maturity to decay. I have neither time nor inclination to attempt to summarise ancient and modern theories as to ultimate atoms, if, or, if not, such exist; as, also, if or not, each atom is sensuous, and that, as a consequence, all bodies have developments of sensuousness in a degree—the combination of atoms in man developing sensuousness in the highest degree; matter combined in living forms other than animal life develops properties very like consciousness, as plants shrink from poisons, and, with apparent avidity, seek wholesome food, in this respect showing an intelligence superior to many forms of animal life. I, individually, should like to believe that plants can think.

But to the purport of this paper: "Old Lessons in Sanitary Science Revived and New Lessons Considered." The most reliable starting point I will take may be found in Leviticus xiv., beginning at the thirty-third verse, where the plague of leprosy is described afflicting the house. Without extracting the whole, the sanitary engineer will recognize "the walls with hollow strakes, greenish or reddish, which, in sight, are lower than the wall." Here is vividly described a tainted subsoil, wet and rotten with saturated filth. The modern remedy would be entire removal of the tainted subsoil, to be replaced by lime concrete, removal of the tainted walls, underpinning with new material, and the introduction of a damp-proof course. Leprosy (or the equivalent of leprosy) affects houses at this day in all parts of the world inhabited by man, from European palaces to the hut of the Esquimaux.* In this malarrangement the savage fares better than the civilized man, as nomad tribes can leave a tainted site, whilst dwellers in villages, towns and cities remain fixed on sites filth-tainted to supersaturation. Seeds of disease ripen in the polluted huts and houses of India, China and Europe, and the North American cities have not escaped this general contamination. Australia and New Zealand have already polluted the sites of their cities to a dangerous extent, so that the mortality returns are no better than those of the old country.

In England we have apparently banished plague, which, however, prevails in the East—Russia, Egypt, and the cities of Asia; but England has ripened the "*germs*" of cholera very recently, and typhus, typhoid, and other forms of fever commonly prevail. That these diseases can be prevented our model prisons bear witness, and modern sanitary works have also materially improved entire town communities. I have used the word "*germ*" as applicable to disease, without in the least being enabled to explain satisfactorily what is meant by it. That types of disease can be introduced and spread will be readily admitted; but that the origin, in each case, is a *germ* is not so easy of proof. It has been suggested that cholera must be conveyed to the human system in water; as, also, that tainted water and tainted milk produce typhus and scarlet fevers; and some say that fluids are necessary to the introduction of those forms of disease into the human system, periods of time being fixed for incubation. There are, however, some facts against this theory being received in its entirety; as for instance, troops and travelers on the march into a virgin country previously unoccupied by man, develop these forms of disease much beyond the assigned period of incubation, and which, under the surrounding conditions, cannot be due to man-tainted earth, air or water; so that the germ theory fails, unless we can imagine that germs of every form of disease which can afflict men or animals

*It may not be strictly proper to use the word "leprosy" as being common to houses; the meaning is, that houses are filth-tainted to an extent which causes rottenness capable of producing disease.

are as eternal as matter, and are dormant in matter until conditions for development are brought about. According to this idea, soil, water and air, and every human body must contain germs of every disease, but dormant, until brought into contact with conditions favorable for development.

The cleanest looking places are not necessarily the safest. A clean looking country house or village, surrounded by pure air free from coal smoke, may have hidden dangers worse than any in a town. Visible dirt is not always the most dangerous, as the rain washes it, the wind blows over it, and the sun dries it. The presence of rats, either in country or in town, is a certain indication of danger, as rats live on garbage. They are usually diseased, and can convey the seeds of disease. It is not possible to predict, in all cases, as to what shall cause disease in excess in any given locality, as filth under peculiar and unknown modifications, or plus an unknown factor, may be sufficient to cause typhoid without the so-called specific germ from a previous case. A telluric influence or an atmospheric influence, which we can neither control nor analyze, in combination with great elemental disturbances, may produce disease in excess. . . .

Past history has, for the most part, consisted of details of the birth, life and death of kings, of their wars and conquests, with a very slight glimpse of the state of the people. In the future, true history will note and record the condition and doings of the people, as constituting the power of the state; but at present the world is very far from this condition. When in this age of general improvement in arts, manufactures and commerce, we find Europe in arms to a greater extent than at any former period, and the people under a load of expenditure the heaviest in the world's history, thoughtful men must pause, wonder and look for some practicable solution. The taxes now being levied and expended on soldiers, armaments, arms and ammunition, would more than serve to abolish every city slum and wretched town tenement, admit of the re-arrangement of every city sewer, and pave every street, drain every house, provide a full supply of pure water at high pressure, and constant service, and pay for daily scavenging. When history can detail these things as accomplished facts, it will be worth reading. Sanitary science is new, but it is not, as yet, popular. To remove filth, to promote health and to prolong life, gain little of a stateman's notice in the battle of politics; the work has, however, commenced and is being taken up, both at home and in our dependencies. The Americans are also becoming earnest sanitarians.

There are poverty, vice and crime in Great Britain which, when contemplated in detail, are quite appalling; and these are the outcome of defective statesmanship—and this after years of political freedom and so-called enlightened government. We sanitarians, however, hold that statesmanship which leaves the largest numerical mass of the population in hopeless misery must be defective. This condition of society is not a sound one; and, consequently, is not a safe one. To see the results of despotism and neglect in their most aggravated forms, we must, however, cast our mental vision over the empires of China and Russia, where millions of men know nothing of political and civil freedom, the results being civil commotions, rebellions and civil slaughter, wholesale arrests, wholesale condemnations, wholesale transportations, and wholesale decapitations, which effect nothing worth the trouble. Because the wretched people have no cessation to their persecution, they exist in misery and have no hope.

True sanitary science recognizes the unit, man—looks at the individual, the single family, the single house, the village, the town and the city, as these constitute nations, and as are the individuals, so must be family, town and nation. If, therefore, there is ignorance, wretchedness and vice amongst the lower orders of the people, the leaven pervades the entire nation.

These questions may be termed political, and it may be said that sanitarians have nothing to do with politics. Our reply, if questioned as to this, must be that to govern men is the prime duty of a statesman. But what are the definitions of the word "govern?" To a despot there is only one definition, and that is, repression; which implies every form of cruelty which man ever devised and practiced. To a British statesman I

hope it means to care for the whole people, to educate and protect them in all honest dealings, to repeal all laws which tend to the commission of crime, to abolish class legislation, and to know nothing of party if it leads to faction.

The domestic side of sanitary science deals with home comforts, and the unit in this case is the house, then the village and the town. Houses must be planned, constructed and regulated to afford means of health and morality to the occupants. Villages and towns must be so arranged, built, sewered, paved and scavenged, as to preserve the purity of the soil below and the air above for the benefit of the inhabitants. To secure such ends there must be sewers, drains, pavements, scavenging, and a water supply. Sewering is ancient beyond written records; sewering scientifically is, however, modern, very modern, as some of those who presided at the birth of the modern system of town sewering are happily now living. Edwin Chadwick, C.B., though not a civil engineer, has, through the aid of engineers, done more to found and promote the true principles of town sewering than any other single individual in this generation.

There were sewers and drains in the cities of Asia which are now heaps of ruins. As in these days, so then, where large areas were covered with buildings, and men were aggregated, there would be sewage; and this would be removed by open channels and covered conduits, necessity having been the mother of invention. These ancient cities were, however, not wholly sewered, but only partially. It is very easy to be positive on this point, namely, that sewers and drains were not general, as there are no remains beneath great areas covered by the common people, and the ruins of which would have been found if sewer and drain pipes had ever been laid.

Rome sewered and drained her cities, public buildings, baths, and palaces from a very early period of her history, and the ruins are there to this day. Pliny describes sewers in some of his letters to the Emperor Trajan. There were not only sewers, but there was also river pollution. The great cloaca sewer of Rome emptied sewage into the Tiber; and Pliny directs the attention of the emperor to a case in a provincial city, where certain banished men resided, apparently living in ease and idleness. There were sewers in the district, and a polluted stream flowed through it, which had become a great nuisance, and was complained of by the inhabitants. Pliny, in this case, suggests that the idle, easy-living, banished men should be more fittingly punished by being made to cleanse the foul sewers, and for the future prevent river pollution. Trajan at once consents to so reasonable a proposition. These letters by Pliny are most interesting, in showing how actively he performed his duties, and how minutely informed he kept the great Emperor.

At Sinope, on the Black Sea, money had been advanced to the municipality for a theatre. A bad site was, however, chosen—a swamp—and the building became a ruin before completion, and the money was wasted. Subsequently, a memorial was sent to Rome petitioning for money to construct waterworks. Pliny, in this case, cautions the emperor, and advises that, if the request is entertained favorably, an engineer be sent with the money, that the local authorities may not job it away, as in the case of the ruined theatre. I suppose the emperor did send an engineer, as, in 1855, I saw the ruins of the service reservoirs, which, but for man's destruction, would have been as entire as on the day of their completion, the walls now remaining being sound and massive as when first constructed.

The making of earthenware vessels by means of the pottter's wheel is of very ancient date; and the work of the potter has, amidst all the ruins of ancient cities, been the most enduring. The vast collection of bricks, tiles, tablets, pipes, and vases placed in European museums testify to this fact At some early period earthenware pipes were thrown on the potter's wheel, having sockets for jointing similar to those now made in England. I saw samples in Asia Minor, in 1855, evidently new. They were about 13 inches in length and 5 inches internal diameter, having a socket of about 1½ inches in depth. They were being laid at Kulali, situate on the Bosphorus, to form a conduit to bring water to the barrack hospital. The natives were at work laying the pipes on a contour line, a considerable length of trench being open.

I did not at first see any arrangements for ventilation and wash-outs, and was questioning the engineer officer upon these points, as to whether or not they had been provided for, and making a rough diagram, scratching on the ground with a stick to illustrate my questions. The engineer officer could give no information; but one of the native workmen, who had been listening to and watching us, touched me on the shoulder, and, with a sparkling countenance, said, "*bono-bono*," immediately taking me along the line of aqueduct, and pointed out the structural means I inquired about, both for ventilation and for wash-out.

Aqueduct making is a very old Eastern practice; aqueducts, fountains and wells being common all over the inhabited parts of Asia. Water, as one of the elements necessary to life, was, in a warm climate, sought for and stored carefully. A very meager history of springs and wells would form a large book, and might be as interesting as the most vivid romance. There are holy wells throughout Asia, and there are also holy wells and fairy wells in Europe, novelists having with great effect availed themselves of these superstitions, and woven them into their descriptions of supernatural phenomena. There is, in fact, an enormous amount of superstition, romance and poetry connected with springs. Magical virtues are attributed to many waters, a belief in which leads to incalculable injury.

There are shrines in India within which are reputedly sacred waters, to be washed with, and to be drunk by the pilgrims to secure eternal salvation. On certain days in the year thousands of the natives assemble and encamp round these sacred shrines. The approach to the holy water is by a flight of marble steps, down which perspiring natives, many of whom are crippled and diseased, throng to have a cupful of the fluid. The practice is to pour a cupful over the head of each native, to flow back to the tank, and this hundreds of times repeated during the day, so that it ceases to be water and becomes a vile compound—the washings from the bodies and feet of natives—and this horrible decoction the priests in attendance administer to be drunk by the poor besotted votaries. Cholera usually breaks out amongst the pilgrims at these gatherings, and it would be contrary to the known laws of sanitary science if it did not do so.

Recently there has very properly been a rage for water analyses, many thousands having been made in Great Britain and in British India, and very startling conditions have been revealed. Water which has been considered pure by the inhabitants of English towns has been found to contain a dangerous proportion of polluting matter, to the effects of which they appear to be stupidly apathetic; but the researches in India reveal a state of things almost too terrible to comtemplate. The natives of India are expert diggers of wells and formers of tanks to supply and store water for use; they are also careless of life, committing suicide with apparent avidity, death by drowning being common. It had been observed that at certain Indian stations British soldiers were liable to be afflicted with virulent types of disease—as cholera, fevers, and, at Delhi, carbuncles and sores, the Delhi sores having become a recognized affliction. Inspection was ordered, when it was found that within the province there had been about 1700 carcasses of human beings removed from tanks and wells, the water from which had been regularly used for human consumption. Some of the worst wells were ordered to be cleansed, when many human bones were removed from them. The tanks in use are open, and the surrounding ground slopes towards the water; over the surface human excrement is spread, and the natives both wash clothes and bathe in the water they use for cooking and drinking. High caste apparently affords no protection, but acts in a contrary direction. Calcutta is supplied with filtered water, but high-caste natives decline to use it. A native water-carrier was observed filling his skin at a stand-pipe with filtered water, but when about three parts filled, he went to the nearest puddle, and with his hands proceeded to fill his vessel. An Englishman, observing him, asked what he was doing, when he replied, "Making Ganges water for master."*

* Great improvements have been made at stations throughout British India in improving and in guiding water-supply sources, both tanks and wells, to prevent pollution; these improvement works are now going on.

Some medical men state that pure water is absolutely necessary to health; others send their patients to drink the most abominable compounds at English and foreign spas. Pure water is a rarity in nature, and where it is found it must be protected with great care, as it is a powerful solvent and greedy of impurities. The solvent property of rain-water, which is the nearest approach in nature to pure water, is probably amongst all the elements the most powerful agent in moulding and disintegrating the solid earth. By way of illustration, the river Thames may be taken. The water of this river contains, in round numbers, about one ton of bicarbonate of lime in each million of gallons, when the water is clear, bright, and sparkingly transparent. The daily supply pumped into London is now about 135,000,000 of gallons, so that 135 tons of bicarbonate of lime is combined with the supply of each day's water, or upwards of 49,000 tons per annum. The average flow of water down the Thames may be taken as 1,000,000,000 gallons per day; so that about 365,000 tons of bicarbonate of lime is washed down per annum from the Thames alone. About four-fifths of the dry land of the earth contain lime, or are limestone, upon which this dissolving action of rain water is unceasing; so that the whole of the solid earth above sea level may be silently washed and wasted down into the great salt ocean. Soft water being so powerful a solvent, is economical for washing, but it is vapid for drinking, and it is liable to produce diarrhœa when peat-tainted. It has not been proven that hard water (hard as Thames water) is injurious to health; it has, however, been demonstrated that it is a great protection to health when it has to be brought into contact with metals—lead, zinc, and some other substances. It is the duty of the sanitarian to obtain clean water, and to preserve it fresh, cool, and clean; but pure water—in the full sense of the word "pure,"—I do not believe to be necessary to health—as spring, stream, river, and well waters necessarily contain salts of the rocks they come into contact with, and these are the waters which are the most largely obtained in nature, and in by far the most cases can alone be obtained, and must, therefore, be accepted. Contaminated water must be dangerous, and should always be avoided. Contamination is not, however, the most dangerous when the water is most visibly polluted. The turbid waters of the Nile, in Egypt, and of the Ganges, in India, are taken for use in preference to all other water. These mighty rivers are, however, usually turbid, the suspended silt acting as a disinfectant.

The filthiest and most dangerous water to drink is well water, human-excreta tainted, which water may be clear and sparkling. Surface water flowing down brooks and rivers, though visibly polluted, does not appear to be as injurious as tainted well-water, earth and air being purifiers of surface water. Water, when inclosed and stagnant, as in wells, pipes, or small unventilated tanks, and especially when affected by liquid or gaseous impurities, becomes stinking and unwholesome. In water works the water to be impounded in reservoirs should be gathered from the cleanest possible sources, and should be preserved clean. Sand filters should be close to the service reservoirs, which should be covered and fully ventilated. The supply from the reservoir and the supply mains should be direct, and the mains should be so laid and connected as to produce continuous circulation, as water retained a long time dormant in "dead ends" rapidly becomes deteriorated. The best water supply will be one which secures the purest source, and by the works of storage and distribution preserves it the purest up to its delivery for use.

Bathing and washing are necessary to health, but there are many towns in Great Britain and Ireland without adequate means for bathing and washing; and, as a consequence, the people do not bathe and are not clean. Baths are common in better-class houses, though by no means as common as they should be. The "tub" is, however, used as a substitute. The poor cannot provide their own baths. These ought, therefore, to be provided for them by the municipal authorities in the best and cheapest form, and in the most convenient positions. With the baths should be wash-houses, where water, soap, and all the apparatus necessary for clean and rapid washing, drying, mangling, and ironing

should be made available at the least practicable cost, and if sites are judiciously selected, and there is no extravagance in the construction and management, there need be no loss. But a small rate in aid, if required, will be a saving indirectly in promoting cleanliness, sobriety, and improved health.

A writer I have before quoted remarks that in Japan bath-houses exist in great numbers in the towns, where warm water is provided at a small cost. These baths are for the benefit of the poorer classes, who use them in great numbers; as regularly as evening comes crowds of Japanese men and women go to bathe. There are ranges of box-shelves where the clothes are placed, whilst the individual steps into the bath, emerges from it, well rubs the skin, dresses, and departs clean in person. In Great Britain, at this day, thousands upon thousands of the poor are never washed clean from their birth to their death, unless they go to prison or to the workhouse. There is no bathing accommodation provided. At all schools there should be baths, and complete washing should be a part of education, as those who are accustomed to regular personal washing in youth will not subsequently abandon it.

Sanitary science has, during the last half century, probably made most progress in England; but then this island is a very small spot on the globe; and even England—free, rich, compact, and educated as it is—only progresses slowly. It may, however, be interesting to this meeting to learn that there is an Association of Municipal and Sanitary Engineers and Surveyors to the number of 205, and that 197 towns and districts are represented by the members. The extent of work executed might be indicated by the make of earthen ware pipes and other sanitary articles, if a reliable return could be obtained. The Messrs. Doulton are making about 1,300 miles of drain-pipes per annum, besides many thousand soil-pans; and this may be about one-tenth of the entire English make of sanitary articles. There is not time in a public address to deliver a closely-reasoned essay, and a popular address is not, I assume, expected to be other than discursive. The following remarks may interest the public, though they may not teach much to the educated engineer:

SEWERS AND DRAINS.

There are good and bad sewers and drains, and the public should know some of the reasons why this is so, and then they may refrain from condemning sanitary works in general. Sewers and drains have been formed which are so defective as to be a cause of serious nuisance; they are too large, have wide and flat bottoms, the materials are bad, and the construction worse. It is possible to damage a town by defective works, and so bring discredit on sanitary science. I will attempt to describe how a town ought to be sewered, and how houses ought to be drained, to fully answer the purposes intended. Correct plans and sections are required upon which to lay out the system of sewers and drains to be constructed; the depths of the cellars should be figured on the sites of houses; the relative levels of the streets may be indicated by contours, and on the sections the strata should be shown by colors. A careful engineer will test the strata by boring and trial holes. Full details how to lay out sewers in right lines, both on plan and in gradient, are given in the "Suggestions" published by the Local Government Board.

An engineer should settle at the commencement what duties the sewers will have to fulfill. If the town has manufactories consuming and polluting much water, the question may arise, if or not this polluted water is to be removed by the town sewers; there will also, in some cases, be a question of injurious fluids, such as tan-pit refuse and pickle-waste from brass founders, lacquer manufacturers, and tin-plate workers; there are also dye waters and soap-waste from woolen manufactories—some of these fluids can be treated on the premises to precipitate the solids and disinfect and clarify the fluids, and, consequently, where there is no land available for sewage filtration, the manufacturers may reasonably be called upon to clarify their polluted liquids—and not pass them in their crude state to the sewers. There are wet and dry subsoils. Sewage will, upon good gradients, flow to any point required by gravity; in other cases there

may be a flat area with a wet subsoil, and a swamp for an outlet, or this may be below the river or sea level. In such cases pumping may have to be resorted to, and then it is desirable to reduce sewage to a minimum. The subsoil should have independent drainage, and the sewers and drains should be water-tight, surface water, including rainfall, being otherwise provided for.

To construct water-tight sewers and drains requires the best materials and the most careful workmanship, but these, indeed, are necessary under all conditions. In a wet subsoil land-water should be excluded; in a dry subsoil, the sewage should be prevented from leaking out of the sewers. In the foregoing remarks extreme cases of wet and dry are contemplated. If sewage has to be pumped and has to be clarified by irrigation, the volume to be dealt with should as near as practicable be a constant quantity. If, however, there is a free outlet by gravity, the sewers may be allowed to partially receive both subsoil and surface water; only, however, to some known and limited extent. It is an advantage to have a wet sewer rather than a dry one. Sewage flows intermittently during portions of each day, when the inhabitants are using most water; if there is no subsoil water, the sewers at intervals may be comparatively dry, admitting of deposit. A steady continuous flow of water through sewers sufficient to maintain a regular current, and not more than a few inches in depth in the main sewers, will be an advantage. Main sewers should ordinarily be laid at a depth sufficient to admit of the deepest cellar being effectively drained, the invert of the branch drain being at the least 1 foot below the cellar floor, the fall of the house drain being not less than one in sixty, and entering the main sewers not lower than half its diameter. These remarks are of course general, and cannot in all cases be acted upon, as many towns have low sites which cannot be effectively sewered and drained without special means (air-valves) to prevent cellars being flooded by back water from the sewers, or by special pumping. House drains, as a rule, should be outside the basement of the houses. But where houses are built in streets, and the kitchens are at the back, the drain must cross the basement unless back drainage is adopted, when no drain need enter the basement. Much has been written and said both in favor of back drainage and against it. I have had twenty years' experience of back drainage, and know nothing but good of it. It has been said that it is an interference with the rights of private property; that the drains will choke, and then there must be trespass to find out the point of failure. My reply is that back drains may be so laid that nothing but gross usage, amounting to willful action, can choke them; and even in such a case they will be freed and cleansed without trespass, as manholes and flushing will enable them to be so cleansed. To enable sound sewers and drains to be constructed, the trenching must be true, and the bottom to receive sewer or drain must be absolutely sound and solid. There must be no mistake here, or the work will soon be a nuisance and a ruin. Sewers and drains may become broken-backed; then there will be leaking joints or saturated subsoil, and a choked sewer or drain will bring discredit upon sewering. If the bottom of a sewer or drain-trench is not sound, it may be made so by cement concrete, and in loose wet quicksandy ground sewers and drains should be covered with concrete. Sewers and drains will work better, and be maintained in better order, if subjected to regular and properly-graduated flushing at short intervals. It is possible to overflush, and so injure the sewers. As much water as will give a velocity of about 6 ft. per second may be admitted; greater force, to give a quicker velocity, will be liable to injure brickwork, and blow or force open pipe joints.

Waterclosets and sinks should be against outer walls; should not have continuous flue-like connections with the sewers, but have a severed connection, and means for full external ventilation. Every public building, however large, and every house, however small, should be so drained as to afford no possibility of sewage gases entering, and they should stand absolutely free from the sewers, though perfectly connected with them; this might be a law without any exception. At present almost every public building and house in London is in direct communication by the drains, with

the sewers, so that sewerage gases pervade them; there are open sewer ventilators in the streets, which serve to dilute the sewage gases, and the enormous number of houses perform a similar purpose, and it is this dilution which prevents the full amount of mischief from being experienced; but there is a danger in it, and this ought to be avoided. This is to be done by absolute isolation and external ventilation above the roofs of the houses. In Leeds, for a population of 320,000, there are upwards of 20,000 openings from the sewers acting as ventilators, which have been in use more than seven years. This is an example other towns may follow with advantage. Perfect sewering requires perfect street paving and perfect street cleansing. Scavenging must, in all cases, be a work of the municipality, or other local governing body. Contract work should be avoided. The work of scavenging should be paid by rate, and this rate should be general.

Waterworks should, in all cases, be in the hands of the local governing body. The service should be constant and at high pressure, with fire service provided for. Water should be laid on to every house and to every tenement; there should be no exception. The service pipes may be of wrought iron, with screw joints, and all the taps should be "screw-down." If the services are taken within the houses and tenements, and the service is high pressure and constant, there will not be much willful wasting of water, and house taps will not be stolen, as waste of water, when at high pressure, will be very disagreeable within a house. Fix stand-pipes in streets and roads, as is done now, and the waste will continue to be unceasing, because it will not inconvenience any one, as when it is within doors. The poor cannot have a full and fair use of water if it is alone obtainable from external stand pipes, as this involves carrying and storing within the tenement. It should also be remembered that one gallon of water weighs 10 lbs., and that fifty gallons weigh 500 lbs., and this will only be ten gallons per head for a family of five persons. The labor required to carry 500 lbs. of water each day, or eighty tons per annum, will simply be enormous, and ought not to be expected from the poor tenant. Serve the water within the house, have necessary supervision, and take charge of repairs; the inhabitants will then be properly supplied with water, and cannot easily waste it. Before closing these brief and imperfect remarks I may glance at a few works recently executed, or which are now in progress.

Calcutta has been partially sewered, Bombay is now in course of being sewered, and preparations are in progress for sewering and draining other Indian cities. Sewerage works at Berlin are also in progress, to be completed with sewage irrigation. Dantzig has been completed, with sewage irrigation added; and main sewerage plans are being prepared for other Continental cities. At Warsaw, with a population of 350,000, the estimate for sewers is £600,000. Buda Pesth, population 270,000, main sewering under consideration. St. Petersburg, population 670,000, estimate for sewers £3,000,000, to include pumping and sewage purification. Munich, population 250,000, estimate for sewering, £600,000. Dusseldorf is to be sewered by Messrs. Lindley, of Frankfort. Messrs. Lindley have sewered Frankfort-on-the-Maine, population 125,000, cost £380,000. Out of 6,800 houses, 5,200 have been completely drained, and in the town there are about 22,000 water closets. At present the sewage goes into the river Maine, but it is to be intercepted and clarified. The Prussian Government insists on sewage clarification, which, at present, is stopping sewering on the Rhine cities, where it is very much needed. The water of the Rhine is, however, used for domestic purposes by the population on its banks, and it ought, therefore, to be preserved free from sewage.

French and Belgian towns remain with cess pools; even Paris and Brussels, with their enormous and costly main intercepting sewers, are cities of cesspools, and I do not know of a single well-drained city in Italy. We are met here in this ancient city of Exeter to discuss sanitary science and preventive medicine, engineering and sanitary construction, meteorology and geology—to give information and to receive information on subjects which we consider to be of vital importance to each individnal man, to each town and to each nation; but when

we read the current newspaper literature of the day, we seem as men beating the air. Statesmen pay very little attention to our subjects, but starve labor by conscription, impoverish populations by taxation, and, at enormous cost, provide the most refined and terrible weapons for human destruction. We are in the midst of a war *furore*, and sanitary works can have no solid and satisfactory progress under existing conditions. There is over the length and breadth of Europe a rampant military spirit: armies, armaments, ironclads, and 100-ton guns, attract most attention. The people are summoned from far to witness autumn manœuvres conducted by emperors, as if soldiers were the beginning and ending of human progress and civilization. The Americans appear to be the only sane nation. The governments of the Old World are drunk with military ambition.

EDISON'S ELECTRIC RAILWAY ECONOMICALLY CONSIDERED.

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Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE principles essential to the successful use of electricity as a means of transferring energy, and its economical conversion into work, were conceived by Mr. Edison long before his labors upon the telephone and electric lamp gave him time to verify his theories practically; and although these principles apply to all machines which convert electrical energy into work, it first assumed practical shape in the development of an electric railway system, including not only the locomotive but a complete system of signals, brakes, and switches, operated by electricity. The advantages resulting from the use of electricity in operating railroads are numerous. Economy is of prime importance. The older form of Mr. Edison's dynamo-electric machine will convert ninety and seven-tenths per cent. of the power developed into electrical energy,* the remainder being lost in friction of belts and shafting, and an inappreciable amount in local currents.

In the improved form of dynamo the loss from friction will be considerably reduced, the engine being connected direct to the armature shaft, and both engine and dynamo secured to one rigid cast-iron sole-plate.

The dynamo as constructed for railroad purposes will be capable of converting one hundred and twenty horse power into electrical energy without heating the machine appreciably, the internal resistance being only one-thirtieth of the total. The available energy is therefore twenty-nine times that lost in the machine.

It is well known that a motor can be driven under such conditions that ninety per cent. of the electrical energy required to drive it will be returned in work, and upon a railway, under varying conditions of speed, eighty per cent. will represent a fair average.

If the effective conversion of the dynamo be assumed as ninety per cent., twenty-nine thirtieths or eighty-seven per cent. is available on the line, and eighty per cent. of this, or sixty-nine and six-tenths per cent. of the energy expended is returned in work by the electric locomotive.

Let it also be assumed that, during wet and foggy weather, the leakage from the conducting rails reduces the efficiency to fifty per cent. or half the original amount. Assuming that the Porter-Allen high-speed engine will develop one indicated horse power for two and one-half pounds of coal, five pounds will be required for a horse power developed in the electric locomotive, when the road is in bad condition and locomotive working to disadvantage.

Careful tests of the best type of steam locomotive give an average of six pounds of coal per indicated horse power,* when special skill and attention are called into

* "Scientific American," May 15, 1880. Tests made by Profs. Brackett and Young, of Princeton College.

* "Engineering," Vol. 29, Nos. 756-757. Tests of a Baldwin locomotive.

requisition for firing and running the engine. Under these circumstances, comparing the unfavorable conditions for electric locomotives with the most favorable for steam we have five-sixths the consumption of coal.

The steam locomotive consumes sixteen per cent. of the power developed in overcoming friction in the complicated working parts, whereas the electric locomotive, with its few working parts and simplicity of arrangement, will consume, at the most, but six per cent., a gain of ten per cent. over the steam locomotive.

The ratio of coal consumed per effective horse power applied to draw the load will be as five and thirty-hundredths pounds to seven and fourteen-hundredths pounds, or twenty-five and one-half per cent. in favor of the electric locomotive. It is well known that the amount of unconsumed coal thrown from the stack by the blast in anthracite burning locomotives, drawing fast passenger or heavy freight trains, is often twenty per cent. of the entire amount, and in bituminous burning locomotives is never less than five per cent. in unconsumed hydro carbons and cinders. It is also stated on good authority* that, from improper attention to the firing and running, the amount of fuel is usually increased from twenty-five to fifty per cent. above what is necessary with proper care. Assuming as a fair average twenty-five per cent., including in this all contingencies, the coal per effective horse power in the two cases will be in the ratio of five and thirty-two hundredths pounds to eight and ninety-three hundredths pounds, or forty and four-tenths per cent. in favor of the electric locomotive.

The high and mean economy of the steam locomotive have been compared with the least economical duty of the electric locomotive. A comparison with the most uneconomical performance of the steam locomotive is not necessary, but the ratio of the mean economy of both will present them in a fair light.

It has been stated that the older form of dynamos show an efficiency of ninety and seven-tenths per cent.

Taking advantage of the experience gained in their construction, by the tests subsequently made upon them, and embodying the results of numerous experiments in the construction of the one hundred and twenty horse-power dynamo, Mr. Edison is confident that the efficiency will be increased to the extent that ninety-five per cent. of the power developed will be converted into electrical energy, and twenty-nine thirtieths, or ninety-one and eight-tenths per cent. will be available. Of this we will assume the average loss from leakage to be ten per cent., which leaves eighty-two and six-tenths available on the line. Assume, as before, that eighty per cent. of this is returned in work by the motor, or sixty-six and one-tenth per cent. of the original power. At two and one-half pounds of coal per horse power at station, the consumption per horse power returned by locomotive will be three and eight-tenths pounds, or four pounds with six per cent. lost in friction of motor.

The ratio of mean economy for both is therefore four pounds to eight and ninety-three hundredths pounds, or fifty-five and two-tenths per cent. in favor of the electric locomotive.

The foregoing comparisons apply to stationary motors as well as to locomotives, excepting that in the first the economy is constant, but in the second it changes slightly, owing to the variation in resistance as the locomotive passes over the line. When Mr. Edison first made public his opinions and purposes, they did not awaken engineers to serious thought, but, on the contrary, it was to them a pleasant diversion, and they were inclined to look upon it as an eccentricity of genius, not in any way adapted to practical use. While not assuming to know what power could be returned by the locomotive, they did say that since engines must be used, why not use them where they are wanted to do the work—upon the line?

Mr. Edison fully understood the facts as they were—not as supposed to be—before announcing his views to the engineering public, and close attention to the facts will show that he is correct as to the practicability and economy of a railway system operated by electricity. As to the consumption of coal per effective horse power, the comparison has been already made. The economy in fuel is obtained by substituting the mos

* Vose's Manual for Railroad Engineers, Chap. XVII.

approved form of boilers and economical type of stationary engines for the present locomotive, in which imperative practical considerations prevent any approach to the economy attained by the stationary type. The saving by this method is so great that, after the efficiency has been reduced by loss from conversion into electrical energy, leakage upon the line, and loss from reconversion and in friction of working parts, the economy is still twice that of the steam locomotive.

The stations where the electricity is produced, if located ten miles apart, could be built and and equipped, according to present estimates, at much less cost than the equipment in the present system. The depreciation of the plant and locomotive would not be one-fourth of the present depreciation, as stationary engines are used and skilled attendance is employed; also the mechanism of the electric locomotive is very simple, and has few moving and no reciprocating parts to keep in proper alignment, therefore none of those irregularities of motion, which subject the present locomotive to continual shocks and sudden strains, and which are the cause of rapid depreciation.

The engine requires but one man of ordinary intelligence for driving and attendance, while at the station ability of a higher order is employed, so that, by judicious management, economy of fuel is attained, and proper care of plant ensured. From this central source of power is obtained the agent by which all the switches and signals are made automatic, or they can be worked by an employee from a central point on the section. The signals at night are lighted and extinguished by the same, which also furnished power to the brakes, and another circuit from the rails gives out light in the cars. For railroads with heavy traffic and worked up to their capacity, estimates have been made which, if approximately correct, show that the cost of operating would be reduced certainly one-third, and upon narrow gauge roads, for thinly-settled and mountainous districts, the first cost of equipment, as well as economy in operating, is much in favor of this system. In mining regions, where ores have to be transported to a distance and over heavy grades, the locomotive is not limited in hauling capacity to traction, but by a mechanical device the locomotive obtains a firm hold upon the rails, and all the power can be directly exerted in drawing the locomotive and cars attached.

When upon a level part of the line, the gripping device is detached and traction alone is relied upon, and the train moves at a higher rate of speed.

The power required in each case would be nearly constant, but speed would be less upon grades. On large plantations, where the tram cars are drawn by mules, and locomotives are inadmissable on account of sparks, the electric locomotive would be invaluable, and upon elevated and surface railroads in cities, in tunnels, and in mines, where the atmosphere is contaminated with suffocating and poisonous vapors from the steam locomotive, it will be a blessing welcomed by all mankind.

REPORTS OF ENGINEERING SOCIETIES.

At the twenty-eighth annual meeting of the American Society of Civil Engineers, held November 3, 1880, the following officers were elected for the ensuing year: President—James B. Francis; Vice-Presidents—Ashbel Welch, Octave Chanute; Secretary and Librarian—John Bogart; Treasurer—J. James R. Croes; Directors—C. Vandervoort Smith, D. J. Whittemore, Joseph P. Davis, G. Bouscaren, William H. Paine.

American Mechanical Engineers.—The first annual meeting of the American Society of Mechanical Engineers began in this city November 4. About sixty members were present. Prof. R. H. Thurston, of Stevens Institute, presided. The secretary reported an enrollment of two life members, one hundred and sixty-one active members, seventeen associates, and nine juniors. The president submitted the following list of papers to be read before the society:

"Friction as a Factor in Motive Power Expenses," Prof. John E. Sweet; "An Adaptation of Bessemer Plant to the Basic Process," Prof. Holly; "Measurement of the Friction of Lubricating Oils," C. J. H. Woodbury; "Strength in Machine Tools," Charles T. Porter; "The Efficiency of the Crank" and "Adjustment of Cushion in Engines," S. W. Robinson; "A New Type of Regenerative Metallurgical Furnace," Prof. Reese; "Standard Screw Threads," George R. Stetson; "On Practical Methods for Greater Economy of Fuel in the Steam Engine," Allan Stirling; "Putting a New Crank pin in the Crank of the Steamship Knickerbocker," Lewis Johnson; "Mechanical Correctness," Charles A. Hague;

"Packing for Piston-rods and Valve-stems," Prof. Lyne; "Study of the Mechanical Theory of Heat," Prof. Wolff; "The Metric System—Is it Wise to Introduce it into Our Machine Shops?" Coleman Sellers.

ENGINEERING STRUCTURES.

THE ORENBURG BRIDGE OVER THE VOLGA. The new bridge which has been built for the Orenburg Railway over the Volga at a distance of 17 versts from Syzran, in the Saratov Government, is completed. The great bridge at Sloerdyk, over the Hollandsch Diep, is shorter than this Volga bridge by six meters. The length of this new bridge is stated to be 696 saschenes, or 1485 meters=1623.986 yards. Its building was commenced on August 17, 1877, so that it has taken just three years to finish. The cost has been 4,630,000 roubles, or nearly £694,500. Four hundred thousand pounds of iron, or 6,552,400 kilogrammes= 5149 tons very nearly, have been employed in the construction. The bridge rests on 13 arches, and the plans were prepared by Professor Beleloubsky, of St. Petersburg. The Russian papers boast that neither England, France, Germany, nor even America, have built such long bridges as their own country, but the Victoria Bridge over the St. Lawrence is the longest. After this new Volga bridge and the Dutch bridge, at Moerdyk, over the Hollandsch Diep, already mentioned, the next longest bridges are, says the *Times*, the Dnieper, at Kiev and Krementschok respectively, in the government of Pultova, the former of which is 1081.68 meters (=about 1182 yards), and the latter 975 meters (=1065 yards 2¼ feet) long. Then comes the bridge over the Waal, at Bommel, in the Dutch province of Gelderland, 917.4 meters (=1002 yards 2 feet) in length. Next in length is the great Mississippi bridge, connecting East St. Louis with St. Louis, which was built between 1869 and 1874, and cost ten millions of dollars, or almost three times as much as the new Russian bridge; it is 772.32 meters—884 yards—long, and rests on only three arches, the middle one having a span of 158 meters. The bridge near the mouth of the Vistula, at Dirschau, in East Prussia, follows, and the Dutch railway bridge over the Lek, at Kuilenburg, on the line between Utrecht and Boxtel, which are 706.19 meters (=761 yards 2½ feet) long. Next comes the Britannia tubular bridge, which is more remarkable for its admirable construction than its length of 556.84 meters (=almost 608 yards 2 feet). The bridge between Praga and Warsaw, 507.77 meters (=555 yards) long, comes next; and then the fine Alexander bridge, only finished last year, between the Finland bank of the Neva and St. Petersburg, which is 405.36 meters (=447 yards) long, considerably less than a third of the length of the new Volga bridge.—*Engineer.*

LONDON BRIDGES.—Sir Joseph Bazalgette is one of the most fortunate of English engineers, for after exhioiting his powers in designing and carrying out the vast main drainage system of the metropolis, and the several miles length of Thames Embankment, he has now the privilege of reconstructing some of the principal Thames bridges. At present he is strengthening the Chelsea Suspension Bridge by the addition of a third chain on either side, Messrs. Appleby Brothers, of Greenwich, being the contractors. He will also shortly proceed with securing the foundations of Waterloo Bridge at a cost of £40,000, and enlarging the central opening of Vauxhall Bridge by throwing three arches into one. The most important portion of Sir Joseph's bridge-work will, however, be the reconstruction of Putney and Battersea Bridges at an estimated cost of about half a million. Parliamentary powers for these works will be sought next session.

THE TAY BRIDGE.—The bill for the reconstruction of the Tay Bridge has been thrown out by the Select Committee, so that the matter will now have to stand over until next session. According to the plan of reconstruction laid before the Committee, a plan for which Mr. Brunlees was the engineer, the clear height beneath the large spans would be reduced to 77 feet, and the spans would be carried on brick piers founded partly on the existing caissons and partly on supplementary caissons to be sunk by the side of those now in place. The existing piers of the small spans were also to be strengthened. Mr. John Cochrane, who gave evidence in favor of the scheme, stated that if the proposed plans were carried out the bridge could be rebuilt in two years, while if it had to be entirely reconstructed four years would be required. The Committee, however, did not feel justified in sanctioning the mode of reconstruction proposed, although they agreed that it was desirable that the bridge should be rebuilt, and that the present site was the most suitable.

THE HARLEM BRIDGE.—Together with its approaches, the new Harlem bridge will begin where Madison avenue now ends, and reach to One Hundred and Thirty-eighth street, Morrisania. It will consist of two fixed spans at each end, each of 73 feet, and a draw span of two openings, each to be 150 feet long. This will make the entire bridge about 600 feet in length. There will be five stone piers and two abutments. The center pier is now completed. It is 47 feet in diameter at the base and 36 feet at the top. The second pier on the east side of the river is well under way. The side piers will be 16½ feet wide at the base, 5 feet wide at the top, and 40 feet high. The estimated cost of the piers is $70,000. The superstructure of the bridge will be a plain truss of iron. Its design has not yet been fully determined upon. The height above high water of the middle span will be 28 feet, while that of the fixed spans will be 25 feet. The cost of the superstructure and approaches will be about $130,000. The roadway of the bridge will be 22 feet wide in the clear, and there will be sidewalks on each side 5 feet wide. In Morrisania, Madison avenue will be graded to the slope of the bridge from One Hundred and

Thirty-seventh street. One Hundred and Thirty-eighth street and River avenue will pass under the approach. The masonry will be completed by January 1, and it is expected that the approaches and superstructure will be finished by July 1 of next year. The foundations of each pier are made by driving piles into the bed of the river and cutting them off at a level of 28 feet below high water mark. Upon these is built masonry of cut granite about 40 feet high. The piers are built in wooden caissons, and on these are floated over the piles and sunk with great accuracy. The piles are driven by a hammer weighing 3,000 pounds, which falls 8 feet, and moves the piles not to exceed one-twentieth of a foot at the last ten blows. The piles are so driven into the river bed that they will sustain 20 tons each. The river bed here is of sand and gravel. Mr. McAlpine is the engineer of construction, and the contractor is John Beattie. The amount already paid out upon the work is $40,000—*Iron Age.*

DIFFERENTIAL TRAMWAY AT THE STONE QUARRIES OF LAUFEN, SWITZERLAND. There are two workings at Laufen quarries, of which the eastern one is without difficulty connected with the main line of the Basle-Delle railway; but in the case of the western quarry, where the beds lie at a lower level, on the bank of the River Birs, special means had to be adopted for transporting the stone, the available area for sidings being very limited.

A substantial timber bridge, crossing the River Birs near this place, already existed, from which, leading to the quarry, was a natural incline of about 1 in 17, allowing a tramway to be laid of the same gauge (4 feet 8½ inches) as the main line, with an additional central rack rail, into which was geared a toothed wheel and winch, worked by four men from the platform of a four-wheeled lorry, the ascent of the incline (148 feet long) being accomplished in about fifteen minutes (load not stated).

This arangement answered the requirements satisfactorily until, with an increased demand for the stone, it was found insufficient for the work. Since the spring of 1878 a miniature locomotive, made by M. Riggenbach (the engineer of the Rigi railway) at his works at Aarau, has been employed, and the permanent way of the incline modified as follows:

In addition to the 4 feet 8½ inches track, an inner road of about 2 feet 9 inches gauge has been laid down, the rails of which are slightly higher than the outer ones. The axles of the locomotive are furnished with additional sets of wheels corresponding to the inner track, and a toothed wheel on the driving axle gears with the central rack by which the engine ascends the incline. At the head and foot of the gradient, the inner track and rack rail are gradually depressed, whereby the ordinary driving wheels are lowered to their bearing upon the 4 feet 8½ inches guage, and the transfer from the ordinary track to the inner railway and rack rail, and *vice versa*, is effected without diminishing speed.

The principal dimensions of the engine are:

	Feet.	Inch.
Diameter of cylinder	0	9½
Stroke	0	12½
Diameter of outer driving wheel	0	19½
" inner running "	0	16¾
" toothed wheel	0	17
Pitch of teeth	0	3½
Wheelbase	4	11
Heating surface, fire box 16½ sq. ft. / Heating surface, tubes 112½ sq. ft.	total, 129 sq. ft	
Grate area	4 sq. ft.	
Weight of engine (empty)	5.0 tons.	
" water in boiler	0.5 "	
" " tank	0.4 "	
" coal	0.2 "	
" engine in working trim,	6.1 "	

The usual load on the incline (exclusive of weight of engine) is 15¾ tons, but on emergency the engine is capable of exerting a tractive force of twice that amount, with a speed of from 10 to 12½ miles per hour.

IRON AND STEEL NOTES.

UTILIZING WASTE BESSEMER METAL.—So much loss and annoyance have been caused through rail ends, old rail bars, and many waste forms of old and new Bessemer steel that makers of Bessemer metal generally will be glad to learn that a cheap and thoroughly practical process has been invented by Mr. W. T. Block, of Hannibal, Mo , for double heating and welding two or more pieces into a homogeneous mass to be wrought into merchantable forms. Any suitable forms of Bessemer steel—such, for example, as rail bars—are reduced to uniform lengths with reference to the purpose to which the finished product is to be applied, and arranged in a convenient form on the bed of the heating furnace, forming a pile without any bands or ties whatever, and consisting of as many pieces as may be desired. Having completed this first stage of the process, which may resemble that in ordinary use in the art, if ties or bands are not used therein, the second stage is commenced, which is the first heating, and which continues until the pile has reached, or nearly reached, the weld heat for this metal, which is the more readily obtained and perfectly distributed where rail bar or similar forms are used in the pile because of the free access of the heat to the inner surfaces of the pile, there being no filling to obstruct free play of the heat or to draw from its intensity.

Care must be taken to prevent any such increase of heat as would be sufficient to burn the steel. The pile is now ready for the second heating prior to the removal to the hammer or rolls. The doors of the heating furnace are opened, thus tempering the heat and a sufficient quantity of iron turnings (those from wrought iron producing the best results) are thrown into it and over the pile and bed of the furnace. The workman then proceeds with the second heating and busselling by rolling

the pile over the turnings on the bed of the furnace, the fagots being now in a sort of temporary weld sufficiently strong in bond to keep together in form. The turnings which the pile gathers up, together with those already thrown over it, weld to the pile, and exert a dual influence. First, they protect it from the increased heat at this stage; and, secondly, they assist in the final welding under the hammer or the rolls. The pile, after having reached the end of the third stage, second heating, is ready to be passed under a hammer or through a train of rolls after the manner that obtains in the ordinary course practiced in the arts. Any ordinary furnace may be used to carry out this process where the degree of heat can readily be regulated and controlled. In handling the pile the instruments common to the trade are employed.—*Mining Journal.*

THE DURATION OF STEEL RAILS.—Some experiments on the comparative duration of steel rails of different qualities have been recently completed: they were carried out near the Oberhausen station on the Cologne and Minden Railway. After fifteen years' wear it was found necessary to take up the following proportion of different classes of rails.

	Per cent.
Fine-grained iron rails.....	82.
Ordinary iron rails.....	74.
Puddled steel.....	41 66
Bessemer steel.....	4.71

The iron and puddled steel rails had become useless, chiefly through the tearing and crushing of the head, in consequence of defective manufacture. The following table shows the reduction in the heights of the rails after 15 years' service; the rails were taken from the eastern and western sides of the Oberhausen Station, and the results show an inequality of wear in the two places.

	Reduction in Height.			
	From East Side of Station.		From West Side of Station.	
	mm.	in.	mm.	in.
Fine iron rails from Friedrich Wilhelms-Hütte.....	5.01	1.973	2.94	1.157
Iron rails from the Phœnix Works.....	5.89	2.319	4.05	1.595
Puddled steel from Funcke & Co.....	5.91	2.327	6.06	2.386
Bessemer steel from Hoesch & Co.....	7.12	2.803	5.67	2.233
Bessemer steel from F. Krupp.....	6.33	2.492	5.34	2.103
Bessemer steel from Hoerde.....	6.23	2.453	4.90	1.929

To complete this table, the percentage of rails removed should be added; they varied, as above stated, from 4 or 5 per cent. for the Bessemer rails, to 80 per cent. in the iron rails. The few of the latter which remained showed, however, less reduction in height than the steel rails. The mean wear of the Bessemer rails was 6.08 millimeters (3.778 in.) in the fifteen years, and the number of pairs of wheels passing over them was 8,600,000, the wear corresponding to one millimeter (.04 in.) for 6,065,000 tons.

CLASSIFICATION OF STEELS.—The Société Cockerill, of Seraing, Belgium, arrange their steels into four classes:

1st Class. Extra mild steels. Carbon, 0.05 to 0.20 per cent.; tensile strength, 25 to 32 tons per square inch; extension, 20 to 27 per cent., in eight inches of length. These steels weld, and do not temper. Used for boiler plates, ship-plates, girder-plates, nails, wire, &c.

2d Class. Mild steel. Carbon, 0.20 to 0.35 per cent. Tensile strength, 32 to 38 tons per square inch. Extension, 15 to 20 per cent. Scarcely weldable, and hardens little. Used for railway axles, tires, rails, guns, and other pieces exposed to heavy strains.

3d Class. Hard steel. Carbon, 0.35 to 0.50 per cent. Tensile strength, 38 to 46 tons per square inch. Extension, 15 to 20 per cent. Do not weld, but may be tempered. Used for rails, special tires, springs, guide-bars of steam engines, pieces subject to friction, spindles, hammers, pumpers.

4th Class. Extra hard steel. Carbon, 0.50 to 0.65 per cent. Tensile strength, 46 to 51 tons per square inch. Extension, 5 to 10 per cent. Do not weld, but may be strongly tempered. Used for delicate springs, files, saws, and various cutting tools.—*From Abstracts of Institution of Civil Engineers.*

NEW WELDING PROCESS.—Krupp has recently taken out a German patent for a new process of welding tubes and tires. He draws the tube on a pair of ordinary rolls, and heats the whole length of the portions which are to be welded in a portable fire-box, into which air is blown, so that the heat is directed against the weld. After the necessary heat is obtained, the rolls are set in motion, and the plate which is to be welded is repeatedly drawn through them.

BESSEMER STEEL PRODUCTION.—A table has been compiled from semi-official sources, which shows the extent of the production of Bessemer steel in the world. It is stated at 2,170,287 tons for 1877, whilst for last year it had grown to 2,864,605 tons. The increase was the most marked in the cases of the United States, Great Britain, France, and Belgium, in the order named. The production last year was made up in the following proportions: America, 928,972 tons; Great Britain, 834,511 tons; Germany, 460,000 tons; France, 302,516 tons; Belgium, 155,000 tons; Austria, 110,000 tons; Sweden, 19,306 tons; and Russia, 54,000 tons. Great Britain is credited with possessing the largest number of Bessemer converters—104, Germany, Austria, and Sweden, and the United States following. The production of other kinds of steel, especially of steel made by the open-hearth process, is so much larger in Great Britain than in the United States as to make this country still the largest of the steel-producing nations of the world.

STYRIAN CAST STEEL FOR TOOLS.—Messrs. Böhler Brothers and Company, of Vienna, exhibited, recently, two cases containing fractured specimens of tilted ingots of cast steel for tools, remarkable for extreme regularity of structure, the fractures being of a fine silky character in the harder qualities, and uniformly granular in those of a softer kind. They were made at Kapfenberg and Bruckbach in Styria, by the fusion, in crucibles, principally, of blister and refined forge steels, produced from the spathic ore of the Erzberg of Eisenerz. This is the largest known deposit of that substance, and is also celebrated for the extreme purity of the product, which, though containing less manganese than the spathic ore of Siegen, is almost absolutely free from copper and sulphur. Charcoal and vegetable fuel only come in contact with the tool-steel and all the materials it is made of in the smelting processes where the metal is brought into contact with the fuel. The tilting of the bars is entirely done under helve-hammers, driven by water power, except in some of the larger sizes, where steam is used; but rolling mills are entirely dispensed with. That the hardest, contains tungsten, and has the characteristic almost glassy fracture, due to the presence of that element. Those of a softer character, distinguished as extra hard, medium hard, tough and soft, all contain manganese and silicon in suitable proportion, the latter being derived from the material of the crucible by the action of manganiferous substances added in the fusion.

The following are complete analyses of three qualities:

	Extra Hard. 3.	Between First Quality Hard, and First Quality Medium Hard.	First Quality Tough. 5.
Carbon	1.189	0.943	0.638
Silicon	0.289	0.382	0.383
Phosphorus.....	0.023	0.027	0.029
Sulphur.....	0.008	0 011	0.013
Copper	traces	traces	traces
Cobalt and nickel.	"	"	"
Manganese	0.371	0.328	0.446
Trace by diff'r'nce	98.150	98.309	98.491
	100.00	100.00	100.00

RAILWAY NOTES.

RAILWAY ACCIDENTS.—The Board of Trade reports on several accidents have been issued. On the Midland Great Western of Ireland, on the 15th of July, a slight collision occurred at Mullingar Station between a down passenger train from Dublin to Mayo, and an up passsenger train from Sligo to Dublin, when the latter was being backed along the up line to couple with some carriages from Galway. The collision arose through an error of the signalman, who had forgotten to close the points of a crossover road, so that the train backed across the line, and ran into the passenger train from Dublin standing on the down line. On the 24th August a collision occurred on the south side of Motherwell Station (Caledonian Railway) between a portion of a fast goods train from Greenock to Carlisle, and a passenger train from Glasgow to Carlisle; four passengers were shaken. The goods train, consisting of 44 wagons, brake van, and two engines, was stopped by signal on nearing Motherwell Junction, and restarting broke the coupling between the thirtieth and thirty-first wagons, the rear portion thus detached running of its own accord into a branch clear of the main line, and was not missed by the drivers of the train, till the latter was stopped by signals about 1000 yards beyond. Then one of the drivers observing that there were no signal lights at the tail of his train, ran back, and found fourteen wagons missing. He took no pains to protect his train but remained waiting until he saw something approaching, which proved to be the 9.10 P. M. passenger train from Glasgow to Carlisle, which had been allowed to pass by a signalman, although he had received no signal that the line was clear. This accident appears to have been caused by a curious combination of stupidity, and despite the fact that every means to secure safe working were provided. On the 2nd of August, upon the North British Railway, a passenger train from Morningside ran into the tail of a goods train standing partially inside the Haymarket Tunnel, Edinburgh. Fourteen passengers were injured. This accident appears to have been caused by the neglect of the engine driver to notice that the danger signal was against him at the other end of the tunnel. On the same line, upon the 28th of August, a collision occurred at Pennycuick Station. A passenger train standing at the station was run into by its own engine which had been detached and run to the water column. A porter attempted, at the request of the engine driver, to take back the engine, but having started it was unable to stop, so that the engine struck the front end of the train violently, and threw the last carriage into the well of a turntable. Two passengers were injured.

THE ST. GOTHARD TUNNEL.—The International Commission has terminated the inspection of the Saint Gothard line, and according to its estimate, the entire works, so far, have cost 86,609,282 francs, of which 49,991,139 fr. is in connection with the main tunnel, 34,359,143 fr. for the lines by which it is approached, and 2,600,000 fr. for the Mont Cenis tunnel. The work executed in 1879–80 represents a sum of 36,592,360 fr. The subventions were fixed as follows: Italy, 9,523,840 fr.; Germany, 5,790,436 fr., and Switzerland, 5,751,776 fr.

A LOCOMOTIVE STATION.—An ingenious method, according to *Nature*, for obviating the frequent stoppage of trains at stations, and yet accommodating the passengers from these stations, has been devised by M. Henrez. A "waiting carriage," comprising a steam engine with special gear, and space for passengers and luggage, is placed on a siding at the station, and picked up by the train as it goes past. The latter, by means of a hook on its last carriage, catches a ring supported on a

post, and connected with a cable wound on a drum in the waiting carriage. Thereupon the drum begins to unwind, and in doing so compresses a system of springs, while the carriage is moved at a rate gradually increasing to that of the train. The engine of the carriage then winds in the cable, the train and carriage are connected, passengers are transferred (the carriage being of the American type) from the joined carriage to the train, and *vice versa*, when the two are disconnected, and the engine of the carriage working on the wheels brings it back to the station whence it was taken.

TRAMWAY TO THE GIANT'S CAUSEWAY.—In the last session a private bill was passed through Parliament, viz.: "The Giant's Causeway, Portrush, and Bush Valley Railway and Tramway Act," which authorizes the construction of road tramways on a system differing from that in ordinary practice, and by which a very great saving in the cost of construction and annual expenditure in working expenses is obtainable. The construction of tramways upon this system, at a cost of about £2,000 a mile, instead of the usual £5,000 to £15,000 per mile, is particularly an advantage to countries like Ireland, or remote districts in England, where tramways constructed at the usual cost could not possibly be remunerative. The proposed new system is suitable rather for road tramways, as distinct from street tramways, for connecting outlying towns, villages, quarries, or mines with the large centers, or railway stations, or for opening up any attractive bits of scenery where a railway would be most objectionable. The tramway is laid on a raised siding along the margin of the road, which forms an ordinary pathway for foot passengers, having a stone kerbing along the outer edge, and graveled or asphalted throughout its length. This siding or pathway is raised about 3 inches to 5 inches above the surface of the road, so as to prevent the passage along it of carts or other vehicles, and so dispenses with the necessity of having to pave the tramway with square sets—a very large item in the usual cost of construction—and also prevents the wear and tear of the surface by other vehicles than the tramcars. The formation width of the tramway is from 6 ft. to 7 ft., on the outside of which the usual country road fence or wall is placed; the gauge of the tramway is 3 ft., laid with ordinary railway rails weighing about 38 lbs. to the yard. On the Giant's Causeway and Portrush Tramway the system above described is to be adopted, and steam traction employed, powers for such having been obtained. It is expected that by this tramway a very large tourist traffic to the Giant's Causeway will be accommodated, in addition to the ordinary local passenger traffic, and a large traffic in goods, iron ore and limestone. The tramway will run alongside the platform of the Belfast and Northern Counties Railway Station at Portrush and be also connected directly with the harbor at Portrush; it will also form a junction at Bushmills with the Bush Valley narrow gauge railway; the tramway is expected to be open for traffic by next summer. Mr. W. A. Traill, C.E., late of H. M. Geological Survey of Ireland, is the engineer.

INDIAN RAILWAYS.—The following statistics are given in the recent report to the Secretary of State for India in Council on Railways in India for the year 1879–80, by Mr. Juland Danvers, Government Director of the Indian Railway Companies:

"The length of the whole railway system of India now open for traffic is 8,611 miles, of which 6,073 miles are in the hands of guaranteed companies, 2,363 miles are State, and 175 are native State lines; 6,693 miles are constructed on the 5 ft. 6 in. gauge, and 1,918 on a narrow gauge. During the past year 395 miles—including the Candahar line—of new railway have been opened for traffic. The railway system is not now terminated by the frontier. A line has been taken from Sukkur on the Indus as far as Sibi, a distance of 133½ miles, in the direction of Candahar. Its further extension to a place about 12 miles from Quetta is now being carried on, but operations beyond this point to Candahar are confined to surveys. On the northwest frontier energetic measures have been taken to continue the Punjab Northern Railway to Peshawur across the Indus at Attock. The bridge, which is in course of construction at this place, will consist of five spans, two of 314 ft., and three of 264 ft. each. It is expected that this line will be so far advanced as to be ready for use up to the left bank of the Indus in November, and from the right bank to Peshawur in January next. Turning to Central India, the remaining link in the railway communication between Delhi and Bombay by way of Ajmere will be finished in the course of the present year. The Rajputana State line will then be opened for traffic throughout. Eighty-two miles of the lower portion between Pahlumpoor and Ahmedabad, where the narrow and the broad gauge systems meet, were opened in November last. The other part of the Rajputana and central Indian system connecting Ajmere with Indore and the Great Indian Peninsula Railway, will probably be opened in the course of 1881. With the exception of a gap of 50 miles, it is expected to be opened on the 1st of January next. The bridge over the Ganges at Benares has been undertaken as part of the system of the Oude and Rohilkund Company, and will be commenced forthwith. It will be the largest work of the kind in India, and is to consist of seven spans of 416 ft., the pier foundations being formed of a solid block of masonry 65 ft. long by 28 ft. wide.

"The net revenue derived from all railways in India during the year 1879 amounted to £5,372,596. That from the guaranteed lines was £5,062,188, compared with £5,002,028 of the previous year. The guaranteed interest paid by the Government was covered, leaving a balance in favor of revenue of £313,955. The net receipts of the State lines amounted to £310,408, compared with £200,374 of the year 1878. The gross receipts of the guaranteed lines were £9,765,284, and the expenses £4,703,096. On the State lines the gross receipts were £1,465,824, and the expenses

£1,155,416, showing an average proportion of net receipts to expenditure on the guaranteed lines of 51, and on the State lines of 22 per cent. In making these comparisons, he says, it must be observed that the State railways are for the most part either political lines recently opened, or small branches with little traffic on them and expensive to work, but serviceable as feeders to the main lines. The Rajputana line, running south from Agra and Delhi, may be regarded as an exception to this description. The total net earnings divided over the total capital outlay, both guaranteed and State, yielded a return at the rate of £4 7s. per cent. per annum. The guaranteed lines earned at the rate ot £5 4s. per cent. per annum.

"The capital expended on the Indian railways up to the end of the official year was £123,124,514. Of this £97,327,851 had been expended on guaranteed lines, £24,403,797 on State lines, and £1,392,866 on lines in native States. The capital expenditure during the period covered by this report—fourteen months in the case of the State railways, nine months in that of the East Indian Railway, and twelve months in that of the other guaranteed lines—was £5,388,772. being £883,185 on guaranteed and £4,505,587 on State lines.

"The number of passengers increased from 38,489,586 in the year 1878 to 43,144,468 last year. The proportion per cent. of first-class was .519, of second, 2.049, and of the lowest classes, 97.432.

"The aggregate quantity of goods carried on all lines amounted to 7,876,766 tons as compared with 7,296,335 of the previous year. The amount received for the conveyance of the same was £7,248,752, compared with £6,734,059 in 1878. The chief articles carried were cotton, grain, rice, piece goods, military stores, salt, seeds, tobacco and opium.

"The expenses of working and maintenance during the year amounted to £5,774.510, compared with £5,101,335 of the previous year. The cost of maintenance was £1,463,550, and of working £4,310,960.

"The rolling stock employed in working the railways consisted of 1,850 locomotives, 4,294 passenger carriages, and 34 856 trucks. The total train mileage during the year was 28,915,144, compared with 26,570,395 of 1878. The passenger train mileage was 5,392,544, the goods 13,546,878, the minerals 357,561, and the mixed goods and passengers 8,964 032.

"The goods shipped to India from this country for the use of the railways amounted during the year to 207,743 tons, of the value of £1,578,404, the freight and insurance of which was £315,181. Besides this, 143,279 tons of coal, 1,938 chaldrons of coke, and 8,393 tons of patent fuel were sent out."

ORDNANCE AND NAVAL.

THE NEW FIELD GUN.—The trials made with the new 13-pounder breech-loader at Okehampton Park have been brought to a conclusion. The only defect in the gun is the tendency of the lever handle of the breech to spring up at the shock of the discharge—a defect which very nearly caused a catastrophe last week by the breech-piece of the gun being sent flying to the rear. A new method of securing the breech will probably be considered. In respect of speed the accuracy of firing the gun greatly surpasses those now in use.

BOOK NOTICES.

PUBLICATIONS RECEIVED.

OCCASIONAL Papers of the Royal Engineer Institute.

Le Genie Civil, Tome I, No. 1.

Annual Report of the Chief of Engineers of the United States Army, 1880.

The Textile Manufacturer, Oct. 1880.

MODERN ARCHITECTURAL DESIGNS AND DETAILS.—Part I. New York: Burnell & Comstock.

This advance number of a series of ten parts which, when completed, will be a liberal sized quarto, is full of promise.

Each part is to contain eight lithographed plates. The present number contains:

Plate 1. Perspective and Plans of a Queen Anne Cottage.
" 2. Three Elevations of Same.
" 3. Framing Plans Showing Construction.
" 4 and 5. Exterior Details of Same.
" 6. Interior " "
" 7. Porch and Details.
" 8. Four Piazzas and Details.

All elevations and details are drawn to scale.

The future numbers will contain designs for dwellings, stores, offices, etc. The large number of contributors will ensure diversity of style.

STEAM BOILERS: THEIR DESIGN, CONSTRUCTION AND MANAGEMENT. By WM. H. SHOCK, Engineer-in-Chief U. S. Navy; Chief of Bureau of Steam Engineering, U. S. Navy. New York: D. Van Nostrand.

This long-needed work appears at length in a style and of dimensions commensurate with the importance of the subject. A handsome quarto of 470 pages of text, 36 full page plates, and 148 interspersed wood cuts, is devoted entirely to steam boilers.

The author wastes no space on general discussions or historical sketches. In briefest possible way mention is made of the fact, that in early times cast iron, and in exceptional cases, granite and wood were used in boiler construction, then copper was in favor till 1858, then plate iron was used, and now steel seems likely to become the favorite material, with improved methods of construction. So much is disposed of in exactly one page of the book. The author then introduces the subjects as follows:

"The essential parts of a steam boiler are:

1st. The ashpit or chamber beneath the grate.

2nd. The grate lying between and separating the ashpit from the furnace.

3rd. The furnace or chamber above the grate.

4th. The flues or tubes and their connecting chambers, extending from the furnace to the chimney.

5th. The chimney.

6th. The water-room enclosing the furnace, tubes, flues, and connecting chambers.

7th. The steam-room lying above the water-room."

After explaining very briefly the interdependence of these parts, the author adds:

"It is quite evident that an ingenious engineer could form of the elementary parts of a boiler just enumerated an almost infinite number of combinations; those which have actually been devised and executed are so numerous that a large space would be required to describe them, and their description, for the most part, would be as useless as tedious, as they are to be found extensively illustrated in patent office reports and in existing engineering literature, the present essay will be restricted to a consideration of only such as have been found, by long experience, to meet the requirements of practice, and chiefly of those best adapted for use on board of war and ocean merchant steamers."

The topics treated by chapters are:

I. Introductory; II. Combustion; III. Transmission of Heat and Evaporation; IV. Materials; V. Testing the Materials; VI. Strength of Boilers; VII. Designs, Drawings and Specifiations; VIII. Laying off, Flanging, Riveting, Welding, etc., IX. Shell, Furnaces and Back Connections; X. Stays and Braces; XI. Flues and Tubes; XII. Uptake, Chimney, Steam Jets, Fan Blowers, etc.; XIII. Steam Room and Superheaters; XIV. Setting and Erection of Boilers; XV. Boiler Mountings and Attachments; XVI. Tests, Inspections and Trials of Steam Boilers; XVII. Management of Boilers; XVIII Causes and Prevention of Deterioration of Boilers; XIX. Boiler Explosions.

WAS MAN CREATED? By HENRY A. MOTT, JR., E. M., Ph.D. New York: Griswold & Co.

This work presents in a direct and concise way the belief of the modern evolutionist, and sets forth the phenomena upon which the belief is founded. To quote the author's preface:

"This work is written for the man of culture who is seeking for truth—believing as does the author, that all truth is God's truth, and therefore it becomes the duty of every scientific man to accept it; knowing, however, that it will surely modify the popular creeds and methods of interpretation, its final result can only be to the glory of God and to the establishment of a more exalted and purer religion."

The illustrations, of which there are many of fair quality, are offered, for the most part, to show that the differences in structure between consecutive units in a carefully selected series in the animal kingdom, are no greater than may be reasonably supposed to have arisen from a natural development. So, from the monera and ameba to man, many illustrations are presented to show the character of the differences between the successive steps in the line, or rather lines, of development. Well selected illustrations also exhibit the changes during the growth of mammals from the fœtal stage to the adult individual.

The work is a good one for the library, exhibiting as it does a chain of argument which is satisfactory to modern naturalists, and which seems to gain strength from every new discovery in natural history.

OBITUARY.

Mr. William Minifie, a well known author, died in October at his residence in Baltimore. He was an architect and the author of four important works—one a text book of geometrical drawing, perspective and shadows, with plates; another, a royal octavo text book of mechanical drawing, highly recommended by the London *Art Journal* and the New York *Scientific American;* another, an essay on the theory and application of color; and the fourth, a series of lectures on drawing and design. The octavo edition was introduced into the Department of Art of the British Government at Marlborough House in 1853, and by the authority of the Lords of the Committee of Privy Council for Trade, it was placed in the list of publications recommended to the schools of art and design throughout the kingdom. Up to this date fifteen editions have been published.

Mr. Minifie was born in Devonshire, England, in 1805, and emigrated to Baltimore about fifty years ago. His early efforts were as a shipjoiner and carpenter. In September, 1845, he was elected teacher of drawing in the Central High School of Baltimore, a position he occupied five years. Drawing had not previously been taught in the public schools of the city. The course of instruction adopted was very similar to the Smith system now used in our schools. In 1837 he designed and built the Front Street Theater, which was generally considered at the time equal, if not superior, to any theater then existing in the United States. It was much praised by prominent actors and others for seeing, and for its acoustic qualities.

In 1836 he was elected a member of the Maryland Academy of Science and Literature of Baltimore. This association was dissolved in 1844 for want of support, and Mr. Minifie, as curator, attended to the distribution of its effects. He was one of the original members of the present Maryland Academy of Sciences, and was also a member of Baltimore Chapter of the American Institute of Architects and of the Decorative Art Society. In 1858 he was elected a member of the American Association for the Advancement of Science, but in consequence of increased deafness he has not taken an active part very lately in any of the associations. He was a public-spirited man and interested in all public improvements.